

1
00:00:00,000 --> 00:00:04,440
I'll scope public lecture series it is

2
00:00:02,339 --> 00:00:06,778
my pleasure to be your host I'm dr.

3
00:00:04,440 --> 00:00:08,849
Frank summers of the office of public

4
00:00:06,778 --> 00:00:12,269
outreach here at the Space Telescope

5
00:00:08,849 --> 00:00:14,849
Science Institute and when you came in

6
00:00:12,269 --> 00:00:18,210
if you notice them we have pictures

7
00:00:14,849 --> 00:00:20,368
we call these lithographs this one is of

8
00:00:18,210 --> 00:00:23,189
a brand-new one Nevernever everything

9
00:00:20,368 --> 00:00:25,800
this is the multi-wavelength Crab Nebula

10
00:00:23,189 --> 00:00:27,618
what do we mean by multi-wavelength well

11
00:00:25,800 --> 00:00:29,820
if you turn over you can see that this

12
00:00:27,618 --> 00:00:33,479
individual image the different colors

13
00:00:29,820 --> 00:00:36,090
are composed of light from six different

14
00:00:33,479 --> 00:00:39,269
five different wavelengths okay from

15
00:00:36,090 --> 00:00:41,309
x-ray all the way to radio and we have

16
00:00:39,270 --> 00:00:43,859
some explanatory text you didn't grab

17
00:00:41,308 --> 00:00:47,699
one on the way in for have one now or on

18
00:00:43,859 --> 00:00:55,170
your way out our talk tonight is the

19
00:00:47,700 --> 00:00:56,789
plumes of Europa ice water life which

20
00:00:55,170 --> 00:00:58,948
Susannah thought would be a cool title

21
00:00:56,789 --> 00:01:02,210
to bring in an audience and it is

22
00:00:58,948 --> 00:01:05,009
alright next month we will have

23
00:01:02,210 --> 00:01:07,710
gravitational wave astronomy which is

24
00:01:05,010 --> 00:01:09,689
now a field something we'd been thinking

25
00:01:07,709 --> 00:01:13,129
about for decades and it's now become a

26
00:01:09,688 --> 00:01:16,079
field our local expert and the fructose

27
00:01:13,129 --> 00:01:17,339
the month after that will feature Fisher

28
00:01:16,079 --> 00:01:19,920
is going to talk about one of my

29

00:01:17,340 --> 00:01:23,609
favorite places in the universe star

30
00:01:19,920 --> 00:01:25,290
formation in the Orion Nebula we're

31
00:01:23,609 --> 00:01:27,540
looking forward to hearing that and then

32
00:01:25,290 --> 00:01:30,450
in July we have one of these really long

33
00:01:27,540 --> 00:01:33,450
titles to call with the Milky Way's

34
00:01:30,450 --> 00:01:36,780
bulge from a hypothesized blob to a

35
00:01:33,450 --> 00:01:39,868
remarkably detailed picture talking

36
00:01:36,780 --> 00:01:42,269
about the center of our galaxy and the

37
00:01:39,868 --> 00:01:44,310
stars that orbit around it out in our

38
00:01:42,269 --> 00:01:46,709
center called the Bulge of our galaxy

39
00:01:44,310 --> 00:01:49,350
okay if you want to learn more about

40
00:01:46,709 --> 00:01:51,539
those or remind yourself of them you can

41
00:01:49,349 --> 00:01:53,908
go to our web page if you go to your

42
00:01:51,540 --> 00:01:55,530
favorite search engine and type in Space

43
00:01:53,909 --> 00:01:57,659

Telescope or Hubble public talks you'll

44

00:01:55,530 --> 00:02:00,239

find this page where we have the list of

45

00:01:57,659 --> 00:02:03,649

the upcoming lectures oops there we go I

46

00:02:00,239 --> 00:02:06,868

think my my lasers it's going all right

47

00:02:03,649 --> 00:02:10,020

we have also on the left-hand side we

48

00:02:06,868 --> 00:02:11,939

have the links for the webcasting both

49

00:02:10,020 --> 00:02:13,920

the Space Telescope webcast II and our

50

00:02:11,939 --> 00:02:15,959

YouTube events the live ones

51

00:02:13,919 --> 00:02:18,780

are active now because it's we're going

52

00:02:15,959 --> 00:02:23,129

live now the archived ones go all the

53

00:02:18,780 --> 00:02:26,489

way back to 2014 on YouTube and 2005 on

54

00:02:23,129 --> 00:02:28,889

the STScI webcast site you can also sign

55

00:02:26,489 --> 00:02:31,500

up for our email list which gets you

56

00:02:28,889 --> 00:02:36,449

about two emails a month reminding you

57

00:02:31,500 --> 00:02:38,310

of the lectures upcoming that email is

58
00:02:36,449 --> 00:02:40,530
on here just sign up at the website and

59
00:02:38,310 --> 00:02:42,629
those of you who can't handle going to a

60
00:02:40,530 --> 00:02:44,009
website can write it down on a piece of

61
00:02:42,629 --> 00:02:45,810
paper and hand it to me at the end of

62
00:02:44,009 --> 00:02:48,810
the lecture and I can make sure you get

63
00:02:45,810 --> 00:02:50,219
on the email list if you have comments

64
00:02:48,810 --> 00:02:52,769
or questions you can send them to the

65
00:02:50,219 --> 00:02:57,780
email address public lecture at STScI

66
00:02:52,769 --> 00:02:59,430
dot edu we have social media for both

67
00:02:57,780 --> 00:03:01,530
the Hubble Space Telescope the Webb

68
00:02:59,430 --> 00:03:04,409
Space Telescope and the Space Telescope

69
00:03:01,530 --> 00:03:08,430
Science Institute on Facebook Twitter

70
00:03:04,409 --> 00:03:11,250
YouTube and Instagram I myself am on

71
00:03:08,430 --> 00:03:13,530
Facebook Google+ and Twitter but don't

72
00:03:11,250 --> 00:03:17,789
expect a lot from me ID I spend a lot of

73
00:03:13,530 --> 00:03:19,049
my time doing other a lot of different

74
00:03:17,789 --> 00:03:20,599
astronomy things that I don't have too

75
00:03:19,049 --> 00:03:23,760
much time to do social media

76
00:03:20,599 --> 00:03:26,699
the observatory across the street will

77
00:03:23,759 --> 00:03:29,280
not be open as you might guess from the

78
00:03:26,699 --> 00:03:32,849
weather outside it's cloudy and a little

79
00:03:29,280 --> 00:03:34,799
bit rainy but they also have open houses

80
00:03:32,849 --> 00:03:38,459
on Friday evenings if you go to their

81
00:03:34,799 --> 00:03:40,950
website MD dot space grant dot o-r-g you

82
00:03:38,459 --> 00:03:43,199
will find that page on the on the right

83
00:03:40,949 --> 00:03:45,659
hand side and in that box that says

84
00:03:43,199 --> 00:03:48,179
Observatory status each Friday evening

85
00:03:45,659 --> 00:03:49,620
by about like 5 or 6 p.m. they post

86

00:03:48,180 --> 00:03:52,829
whether or not they're going to be open

87
00:03:49,620 --> 00:03:54,209
for public observing so yet again we are

88
00:03:52,829 --> 00:03:57,209
unable to take you across the street

89
00:03:54,209 --> 00:03:59,519
after the lecture for that tonight to

90
00:03:57,209 --> 00:04:02,209
the public lecture but hopefully you can

91
00:03:59,519 --> 00:04:04,829
find it on one of the Friday nights and

92
00:04:02,209 --> 00:04:10,639
now our news from the universe for

93
00:04:04,829 --> 00:04:13,799
April 2018 our first story unfortunately

94
00:04:10,639 --> 00:04:16,620
is the James Webb Space Telescope had

95
00:04:13,799 --> 00:04:18,989
another launch delay all right and the

96
00:04:16,620 --> 00:04:22,519
NASA press this is the James Webb Space

97
00:04:18,988 --> 00:04:26,250
Telescope it is a six and a half meter

98
00:04:22,519 --> 00:04:26,899
infrared space telescope that was it's

99
00:04:26,250 --> 00:04:28,310
it's

100
00:04:26,899 --> 00:04:30,560

it's really one of the most technically

101

00:04:28,310 --> 00:04:33,620

challenging things we've ever launched

102

00:04:30,560 --> 00:04:35,600

into space possibly the most technically

103

00:04:33,620 --> 00:04:39,860

challenging civilian thing we've ever

104

00:04:35,600 --> 00:04:41,930

launched into space and the NASA press

105

00:04:39,860 --> 00:04:45,979

release stated that the launch window is

106

00:04:41,930 --> 00:04:48,759

now targeted for approximately May 2020

107

00:04:45,978 --> 00:04:52,269

yes we have to wait another year for it

108

00:04:48,759 --> 00:04:55,400

all the observatory but I pulled out

109

00:04:52,269 --> 00:04:57,620

specific quotes all right first of all

110

00:04:55,399 --> 00:05:00,978

all the observatories flight hardware is

111

00:04:57,620 --> 00:05:02,629

now complete okay so if they've got the

112

00:05:00,978 --> 00:05:04,939

spacecraft element and they've got the

113

00:05:02,629 --> 00:05:06,740

telescope element the stuff is complete

114

00:05:04,939 --> 00:05:09,589

and it's all together for the first time

115
00:05:06,740 --> 00:05:12,199
in the Northrop Grumman facility all

116
00:05:09,589 --> 00:05:13,879
right it is undergoing final integration

117
00:05:12,199 --> 00:05:16,939
and test phases that will require more

118
00:05:13,879 --> 00:05:18,439
time to ensure a successful mission we

119
00:05:16,939 --> 00:05:20,538
all remember what happened with the

120
00:05:18,439 --> 00:05:22,300
Hubble Space Telescope having a problem

121
00:05:20,538 --> 00:05:25,009
that needed to be fixed

122
00:05:22,300 --> 00:05:27,860
j2 st is going to be a million miles

123
00:05:25,009 --> 00:05:29,720
from Earth it's not gonna be a low Earth

124
00:05:27,860 --> 00:05:32,689
orbit like Hubble was it cannot be fixed

125
00:05:29,720 --> 00:05:34,490
when it is out there so it is extremely

126
00:05:32,689 --> 00:05:37,279
important to get it right and get it

127
00:05:34,490 --> 00:05:39,379
right the first time as one of the

128
00:05:37,279 --> 00:05:41,448
juniors to engineers says we got to

129
00:05:39,379 --> 00:05:43,848
knock this out of the park a million

130
00:05:41,449 --> 00:05:45,680
miles out of the park all right so yeah

131
00:05:43,848 --> 00:05:47,750
we are taking the time until you to get

132
00:05:45,680 --> 00:05:50,180
it correct and then the other question

133
00:05:47,750 --> 00:05:52,129
people have is about the budget NASA

134
00:05:50,180 --> 00:05:53,780
will provide a new cost estimate that

135
00:05:52,129 --> 00:05:56,000
may exceed the projected 8 billion

136
00:05:53,779 --> 00:05:58,279
development cost to complete the final

137
00:05:56,000 --> 00:06:00,259
phase of testing and prepare for launch

138
00:05:58,279 --> 00:06:03,259
which means that they are currently

139
00:06:00,259 --> 00:06:05,240
evaluating what the delay will cost and

140
00:06:03,259 --> 00:06:09,529
they will provide it to the American

141
00:06:05,240 --> 00:06:11,240
public when they have that okay so it is

142
00:06:09,529 --> 00:06:13,158
still going to do the same great science

143

00:06:11,240 --> 00:06:16,579
we're just gonna have to wait a little

144
00:06:13,158 --> 00:06:18,139
bit longer for it but it is as I said

145
00:06:16,579 --> 00:06:20,870
really important that we get it right

146
00:06:18,139 --> 00:06:22,750
the first time so it's to me it's worth

147
00:06:20,870 --> 00:06:25,280
the extra time ok

148
00:06:22,750 --> 00:06:29,360
second story tonight

149
00:06:25,279 --> 00:06:34,939
planetary construction dust now this

150
00:06:29,360 --> 00:06:38,090
image is up ace of a a disk or actually

151
00:06:34,939 --> 00:06:39,610
a ring around a star that's called HR 47

152
00:06:38,089 --> 00:06:42,908
96 a

153
00:06:39,610 --> 00:06:46,120
okay and it came out in 1999 this is a

154
00:06:42,908 --> 00:06:48,430
Hubble image and I was really excited

155
00:06:46,120 --> 00:06:50,199
when I saw this because I wasn't here at

156
00:06:48,430 --> 00:06:53,168
the time I was up in New York City and

157
00:06:50,199 --> 00:06:55,478

we were discussing the new discoveries

158

00:06:53,168 --> 00:06:59,279

in our own solar system in particular

159

00:06:55,478 --> 00:07:01,829

the Kuiper belt okay this new region of

160

00:06:59,279 --> 00:07:05,138

objects out beyond the orbit of Neptune

161

00:07:01,829 --> 00:07:07,508

all right and this is where Pluto lives

162

00:07:05,139 --> 00:07:10,870

ok Pluto is now the largest member of

163

00:07:07,509 --> 00:07:12,370

the Kuiper belt and so when you look in

164

00:07:10,870 --> 00:07:14,348

the lower right and you see that the

165

00:07:12,370 --> 00:07:17,709

diameter of Neptune's orbit is that and

166

00:07:14,348 --> 00:07:19,778

this ring of material um is just larger

167

00:07:17,709 --> 00:07:21,489

it kind of got us excited because we

168

00:07:19,778 --> 00:07:23,500

were just discovering the Kuiper belt in

169

00:07:21,490 --> 00:07:26,228

our own system and here we were finding

170

00:07:23,500 --> 00:07:27,819

something of the same scale however this

171

00:07:26,228 --> 00:07:31,839

isn't the Kuiper belt okay it's not made

172
00:07:27,819 --> 00:07:34,270
of ice this is made of dust and it's you

173
00:07:31,839 --> 00:07:35,500
don't even expect it to be a fully

174
00:07:34,269 --> 00:07:40,418
formed Kuiper belt type thing because

175
00:07:35,500 --> 00:07:45,038
the star HR 47 96 a is only 8 million

176
00:07:40,418 --> 00:07:47,769
years old but at 8 million years that's

177
00:07:45,038 --> 00:07:48,478
the time scale on which giant planets

178
00:07:47,769 --> 00:07:51,459
form

179
00:07:48,478 --> 00:07:54,550
Jupiter's in such form on timescales of

180
00:07:51,459 --> 00:07:57,088
order 10 million years so seeing a dust

181
00:07:54,550 --> 00:08:01,210
ring that's so tightly correlated here

182
00:07:57,088 --> 00:08:03,278
could indicate that a giant planet had

183
00:08:01,209 --> 00:08:05,680
formed in this system has recently

184
00:08:03,278 --> 00:08:09,038
formed in this system and that makes is

185
00:08:05,680 --> 00:08:11,740
exciting now so we can take this image

186
00:08:09,038 --> 00:08:14,139
we're gonna shrink it and rotate it okay

187
00:08:11,740 --> 00:08:17,680
that's the exact same image okay and now

188
00:08:14,139 --> 00:08:22,300
we have a new image of HR 47 96 a that

189
00:08:17,680 --> 00:08:25,088
looks like that yeah more sensitive

190
00:08:22,300 --> 00:08:28,000
looking deeper and seeing dust not in

191
00:08:25,088 --> 00:08:32,559
just a tight ring but actually spread

192
00:08:28,000 --> 00:08:35,828
out across the system see 47 96 a is

193
00:08:32,559 --> 00:08:39,069
about 23 times more luminous than the

194
00:08:35,828 --> 00:08:42,309
Sun right so therefore it has a lot more

195
00:08:39,070 --> 00:08:44,430
radiation pressure and so while giant

196
00:08:42,309 --> 00:08:47,769
planets formed on order 10 million years

197
00:08:44,429 --> 00:08:50,259
planets like Earth form on timescales of

198
00:08:47,769 --> 00:08:53,139
a hundred million years and in the

199
00:08:50,259 --> 00:08:55,539
process of building up tourists

200

00:08:53,139 --> 00:08:56,759
planets you get a lot of things smashing

201
00:08:55,539 --> 00:08:59,169
together all right

202
00:08:56,759 --> 00:09:01,240
planetesimals accretion and that

203
00:08:59,169 --> 00:09:03,879
produces some dust right planetary

204
00:09:01,240 --> 00:09:08,139
construction dust and the radiation

205
00:09:03,879 --> 00:09:10,269
pressure from 47 96 a can actually blow

206
00:09:08,139 --> 00:09:12,789
some of that dust out of the system like

207
00:09:10,269 --> 00:09:15,578
this alright so the interpretation of

208
00:09:12,789 --> 00:09:18,399
this image is that some of this dust is

209
00:09:15,578 --> 00:09:20,349
coming from the form possibly coming or

210
00:09:18,399 --> 00:09:22,419
as a reasonable hypothesis is that it's

211
00:09:20,350 --> 00:09:24,310
coming from the formation of terrestrial

212
00:09:22,419 --> 00:09:26,110
planets that's kicking up dust and then

213
00:09:24,309 --> 00:09:29,949
being pushed out by the radiation

214
00:09:26,110 --> 00:09:32,649

pressure of this large star spreading it

215

00:09:29,950 --> 00:09:35,230

across the system so that's kind of cool

216

00:09:32,649 --> 00:09:39,129

and here is by the way all of the

217

00:09:35,230 --> 00:09:40,750

details of this so 47 96 a is in that

218

00:09:39,129 --> 00:09:42,759

dark spot there we block it out of

219

00:09:40,750 --> 00:09:44,950

course because if you have the star you

220

00:09:42,759 --> 00:09:47,528

can't see the dust around it you can see

221

00:09:44,950 --> 00:09:49,810

the the ring there's also you notice a

222

00:09:47,528 --> 00:09:52,570

bow shock that curved line because the

223

00:09:49,809 --> 00:09:55,179

star system is moving through medium so

224

00:09:52,570 --> 00:09:57,190

you get a thing and also in the lower

225

00:09:55,179 --> 00:10:01,208

right there's a dark circle there that

226

00:09:57,190 --> 00:10:03,040

is the companion star 47 96 B all right

227

00:10:01,208 --> 00:10:04,389

and actually I what I think is kind of

228

00:10:03,039 --> 00:10:05,110

cool which we didn't mark is in the

229

00:10:04,389 --> 00:10:09,519

lower left

230

00:10:05,110 --> 00:10:11,139

that's a background galaxy so we're

231

00:10:09,519 --> 00:10:12,669

looking at a star in our galaxy but

232

00:10:11,139 --> 00:10:14,528

we're also looking at a background

233

00:10:12,669 --> 00:10:17,229

galaxy in the same image here

234

00:10:14,528 --> 00:10:19,570

alright so we're this may be the dust

235

00:10:17,230 --> 00:10:23,680

kicked up by the construction of planets

236

00:10:19,570 --> 00:10:27,670

in another solar system final story a

237

00:10:23,679 --> 00:10:29,469

cosmology conundrum about a hundred

238

00:10:27,669 --> 00:10:31,750

years ago a little less than a hundred

239

00:10:29,470 --> 00:10:34,690

years ago Edwin Hubble made this diagram

240

00:10:31,750 --> 00:10:37,659

and on this diagram he's plotting galaxy

241

00:10:34,690 --> 00:10:39,519

distance against galaxy redshift and he

242

00:10:37,659 --> 00:10:41,500

found he got a straight line that

243
00:10:39,519 --> 00:10:43,778
galaxies that were further away had

244
00:10:41,500 --> 00:10:46,629
larger redshifts in a linear fashion and

245
00:10:43,778 --> 00:10:49,240
this is the primary motivating evidence

246
00:10:46,629 --> 00:10:51,189
for the expanding universe all right

247
00:10:49,240 --> 00:10:53,139
that space is expanding and therefore

248
00:10:51,190 --> 00:10:56,079
distant galaxies appear to be moving

249
00:10:53,139 --> 00:10:59,649
away faster in a linear fashion

250
00:10:56,078 --> 00:11:01,059
however the slope of it is the expansion

251
00:10:59,649 --> 00:11:02,740
rate of the universe the current

252
00:11:01,059 --> 00:11:05,469
expansion rate of the universe we call

253
00:11:02,740 --> 00:11:06,610
that the Hubble constant unfortunately

254
00:11:05,470 --> 00:11:08,800
he got the Hubble constant

255
00:11:06,610 --> 00:11:10,930
wrong because the way he was measuring

256
00:11:08,799 --> 00:11:12,429
distances depended him on Cepheid

257

00:11:10,929 --> 00:11:14,199
variables and he was using the wrong

258
00:11:12,429 --> 00:11:16,778
type of Cepheid variables so he got it

259
00:11:14,200 --> 00:11:19,060
wrong by about a factor of 10 but

260
00:11:16,778 --> 00:11:23,110
eventually we astronomers got it right

261
00:11:19,059 --> 00:11:25,389
so this plot shows a date on the x-axis

262
00:11:23,110 --> 00:11:27,430
and the value of H naught which is this

263
00:11:25,389 --> 00:11:29,049
Hubble constant starts out in the

264
00:11:27,429 --> 00:11:31,120
hundreds and then finally gets down to

265
00:11:29,049 --> 00:11:33,909
when I was in graduate school

266
00:11:31,120 --> 00:11:37,028
in the late 80s the values were between

267
00:11:33,909 --> 00:11:38,559
50 and 100 so yeah we went from being a

268
00:11:37,028 --> 00:11:41,110
factor of 10 off to being down to a

269
00:11:38,559 --> 00:11:43,059
factor of 2 and this is cosmology a

270
00:11:41,110 --> 00:11:44,680
factor of 2 is good all right I keep

271
00:11:43,059 --> 00:11:46,739

telling myself I'm an astronomer a

272

00:11:44,679 --> 00:11:51,009

factor of 2 is good enough for me right

273

00:11:46,740 --> 00:11:52,570

and so but that's still not good enough

274

00:11:51,009 --> 00:11:55,629

to do what we call precision cosmology

275

00:11:52,570 --> 00:11:58,600

so when the hubble space telescope came

276

00:11:55,629 --> 00:12:00,730

online one of its key projects was

277

00:11:58,600 --> 00:12:03,759

measuring the Hubble constant by getting

278

00:12:00,730 --> 00:12:05,470

accurate distances to near near galaxies

279

00:12:03,759 --> 00:12:08,230

so that we could really measure the

280

00:12:05,470 --> 00:12:13,000

Hubble constant carefully as an HST key

281

00:12:08,230 --> 00:12:15,940

project in the year 2000 that the data

282

00:12:13,000 --> 00:12:19,089

was released and this is a graphic of

283

00:12:15,940 --> 00:12:21,399

the diagram showing that here the points

284

00:12:19,089 --> 00:12:25,600

plotted and plausible values were

285

00:12:21,399 --> 00:12:27,278

between 63 and 77 so that's great we've

286
00:12:25,600 --> 00:12:28,690
you know it's gone from you know being a

287
00:12:27,278 --> 00:12:33,220
factor of 10 off to down to a factor of

288
00:12:28,690 --> 00:12:36,070
2 down to 10% okay we had a difference

289
00:12:33,220 --> 00:12:38,350
of 10% but can we leave that alone

290
00:12:36,070 --> 00:12:40,510
no we're scientists we really want to

291
00:12:38,350 --> 00:12:42,790
beat that down and beat that down so

292
00:12:40,509 --> 00:12:44,708
what they have done with Hubble recently

293
00:12:42,789 --> 00:12:48,309
is they went back and remeasure the

294
00:12:44,708 --> 00:12:51,578
Cepheid in our galaxy the calibration

295
00:12:48,309 --> 00:12:53,979
method as well as doing other things and

296
00:12:51,578 --> 00:12:57,879
we are able in this new paper that just

297
00:12:53,980 --> 00:13:02,199
came out get it down to a range of 72 to

298
00:12:57,879 --> 00:13:07,279
75 success we finally have this Hubble

299
00:13:02,198 --> 00:13:10,399
constant measured except

300
00:13:07,279 --> 00:13:13,459
in the meantime we have developed other

301
00:13:10,399 --> 00:13:15,949
ways estimating the Hubble constant one

302
00:13:13,460 --> 00:13:18,050
of them depends upon measuring the

303
00:13:15,950 --> 00:13:20,150
Cosmic Microwave Background this is the

304
00:13:18,049 --> 00:13:22,039
Coby satellite the first measurement of

305
00:13:20,149 --> 00:13:24,319
the cosmic wave background which then

306
00:13:22,039 --> 00:13:25,939
got refined with the W map satellite and

307
00:13:24,320 --> 00:13:28,310
then got improved as to still a little

308
00:13:25,940 --> 00:13:31,040
bit more with the Planck satellite and

309
00:13:28,309 --> 00:13:33,199
this is measuring the temperature

310
00:13:31,039 --> 00:13:34,519
differences which is basically the

311
00:13:33,200 --> 00:13:37,400
density differences in the early

312
00:13:34,519 --> 00:13:38,809
universe and from that what we really

313
00:13:37,399 --> 00:13:39,769
measure out of the the COTS microwave

314

00:13:38,809 --> 00:13:42,559
background is something we call the

315
00:13:39,769 --> 00:13:45,110
power spectrum which is how much density

316
00:13:42,559 --> 00:13:47,989
is on different scales in the early

317
00:13:45,110 --> 00:13:49,639
universe and from that you know we can

318
00:13:47,990 --> 00:13:51,049
extrapolate through to the rest of the

319
00:13:49,639 --> 00:13:54,470
universe and start figuring out the

320
00:13:51,049 --> 00:13:57,409
expansion rate in particular the second

321
00:13:54,470 --> 00:14:00,019
peak of this power spectrum is sensitive

322
00:13:57,409 --> 00:14:03,110
to the hubble value the expansion rate

323
00:14:00,019 --> 00:14:05,509
of the universe okay and so its location

324
00:14:03,110 --> 00:14:07,610
and its its magnitude gives us a good

325
00:14:05,509 --> 00:14:09,259
estimate of the Hubble constant it

326
00:14:07,610 --> 00:14:11,539
doesn't give us a perfect estimate but

327
00:14:09,259 --> 00:14:13,669
it gives us a good estimate combine that

328
00:14:11,539 --> 00:14:16,159

with two other ways of measuring things

329

00:14:13,669 --> 00:14:18,469

one from supernovae and one from

330

00:14:16,159 --> 00:14:21,980

something called baryon acoustic

331

00:14:18,470 --> 00:14:24,290

oscillations it's labeled Bao I'm not

332

00:14:21,980 --> 00:14:26,800

gonna try and explain that in 30 seconds

333

00:14:24,289 --> 00:14:29,329

here it doesn't work but trust me

334

00:14:26,799 --> 00:14:30,559

combining the three of them the Cosmic

335

00:14:29,330 --> 00:14:33,530

Microwave Background baryon acoustic

336

00:14:30,559 --> 00:14:35,869

oscillations and the supernovae you can

337

00:14:33,529 --> 00:14:38,659

get another estimate of the Hubble

338

00:14:35,870 --> 00:14:40,610

constant independent of the Cepheid

339

00:14:38,659 --> 00:14:46,819

variables and all that and it comes out

340

00:14:40,610 --> 00:14:49,250

to 65 to 69 here's the problem both of

341

00:14:46,820 --> 00:14:51,440

these methods are tried-and-true both of

342

00:14:49,250 --> 00:14:53,960

these methods are we believe are

343
00:14:51,440 --> 00:14:57,170
estimating their errors well all right

344
00:14:53,960 --> 00:15:00,379
the local ones 72 to 75 the large-scale

345
00:14:57,169 --> 00:15:01,789
ones 65 to 69 and the quote from Adam

346
00:15:00,379 --> 00:15:03,679
riess the head of the researcher says

347
00:15:01,789 --> 00:15:06,588
both results have been tested multiple

348
00:15:03,679 --> 00:15:09,319
ways so barring a series of unrelated

349
00:15:06,589 --> 00:15:11,930
mistakes it is increasingly likely that

350
00:15:09,320 --> 00:15:14,570
this is not a bug but a feature of the

351
00:15:11,929 --> 00:15:16,399
universe that are local estimates of the

352
00:15:14,570 --> 00:15:18,500
Hubble value Hubble constant value

353
00:15:16,399 --> 00:15:20,840
differ from our large-scale measure

354
00:15:18,500 --> 00:15:24,230
estimates of the Hubble value

355
00:15:20,840 --> 00:15:26,330
what do we do okay well if you read the

356
00:15:24,230 --> 00:15:29,240
news bag news news about this

357
00:15:26,330 --> 00:15:30,020
astronomers are baffled no we're not

358
00:15:29,240 --> 00:15:33,370
baffled okay

359
00:15:30,019 --> 00:15:35,509
we're intrigued we're excited because

360
00:15:33,370 --> 00:15:38,029
frankly if we knew everything we'd be

361
00:15:35,509 --> 00:15:39,799
out of a job so this gives us something

362
00:15:38,029 --> 00:15:42,620
new there's something new in the

363
00:15:39,799 --> 00:15:44,779
universe it's either our problem which

364
00:15:42,620 --> 00:15:46,220
it's unlikely or there's some new

365
00:15:44,779 --> 00:15:47,899
feature in the universe okay

366
00:15:46,220 --> 00:15:50,750
so of course we can come up with new

367
00:15:47,899 --> 00:15:52,579
ideas and so some of the new ideas are

368
00:15:50,750 --> 00:15:56,720
perhaps there is an undiscovered

369
00:15:52,580 --> 00:16:00,980
subatomic particle such as a neutrino

370
00:15:56,720 --> 00:16:02,450
with mass that changes the measurements

371

00:16:00,980 --> 00:16:03,680
that we would get from one of the one of

372
00:16:02,450 --> 00:16:07,160
these values basically that would be a

373
00:16:03,679 --> 00:16:09,289
large scale or maybe dark matter doesn't

374
00:16:07,159 --> 00:16:10,639
behave exactly the way we think it is we

375
00:16:09,289 --> 00:16:12,409
think Dark Matter only behaves

376
00:16:10,639 --> 00:16:14,720
gravitationally maybe there's a little

377
00:16:12,409 --> 00:16:17,750
bit stronger interaction between dark

378
00:16:14,720 --> 00:16:19,820
matter and normal matter or the most

379
00:16:17,750 --> 00:16:21,649
popular one that you can written

380
00:16:19,820 --> 00:16:23,420
thinking today is what about dark energy

381
00:16:21,649 --> 00:16:25,759
we don't know much about dark energy

382
00:16:23,419 --> 00:16:27,740
we've got a lot of ignorance there maybe

383
00:16:25,759 --> 00:16:30,169
some of that ignorant effects one of

384
00:16:27,740 --> 00:16:33,110
these measures okay so we have a lot of

385
00:16:30,169 --> 00:16:35,719

hypotheses and ideas on what might

386

00:16:33,110 --> 00:16:39,050

resolve this but also I can really say

387

00:16:35,720 --> 00:16:42,379

is stay tuned because we have identified

388

00:16:39,049 --> 00:16:44,089

a discrepancy all right and the process

389

00:16:42,379 --> 00:16:45,379

of science is we're gonna hack at it and

390

00:16:44,090 --> 00:16:47,300

we're gonna hack at it we're gonna hack

391

00:16:45,379 --> 00:16:49,879

at it until either we figure out what's

392

00:16:47,299 --> 00:16:51,679

wrong with our observations or we come

393

00:16:49,879 --> 00:16:53,840

up with a really good idea that can

394

00:16:51,679 --> 00:16:55,549

explain this discrepancy and to me

395

00:16:53,840 --> 00:16:57,740

that's part of the joy and excitement of

396

00:16:55,549 --> 00:16:58,839

science when you find something that you

397

00:16:57,740 --> 00:17:01,460

can't explain

398

00:16:58,840 --> 00:17:03,649

then you're just like oh we got to

399

00:17:01,460 --> 00:17:05,990

figure this out unfortunately it'll take

400
00:17:03,649 --> 00:17:08,089
a decade or two that's actually find out

401
00:17:05,990 --> 00:17:09,380
so stay tuned and keep coming to the

402
00:17:08,089 --> 00:17:11,779
public lecture series I'll make sure

403
00:17:09,380 --> 00:17:15,160
that I have it for you all right okay

404
00:17:11,779 --> 00:17:19,069
and that's our news from the universe

405
00:17:15,160 --> 00:17:22,160
our featured speaker tonight is Susanna

406
00:17:19,069 --> 00:17:25,099
de use to ax she has been here for what

407
00:17:22,160 --> 00:17:28,340
10 years and she works in the AI NS

408
00:17:25,099 --> 00:17:30,740
division on the Hubble instrument Wide

409
00:17:28,339 --> 00:17:34,250
Field Camera 3 or we just call it with

410
00:17:30,740 --> 00:17:35,900
c3 and

411
00:17:34,250 --> 00:17:37,819
I asked her for some interesting things

412
00:17:35,900 --> 00:17:42,280
about her and she said that she fly

413
00:17:37,819 --> 00:17:44,269
Fitch's fly fishes from her kayak

414
00:17:42,279 --> 00:17:48,319
combining kayaking and fly fishing

415
00:17:44,269 --> 00:17:50,960
together and that once she did jump out

416
00:17:48,319 --> 00:17:54,139
of an airplane even as well as having

417
00:17:50,960 --> 00:17:56,900
never been on the Space Shuttle okay so

418
00:17:54,140 --> 00:18:07,740
here to tell us about Jupiter's moon

419
00:17:56,900 --> 00:18:10,910
Europa is Susanna Deus Troy thank you

420
00:18:07,740 --> 00:18:10,910
[Music]

421
00:18:12,640 --> 00:18:29,270
and I think I'm number one or three

422
00:18:16,400 --> 00:18:31,280
maybe I'm three okay all right so we're

423
00:18:29,269 --> 00:18:35,950
going to talk a little bit about the

424
00:18:31,279 --> 00:18:35,950
water plumes what's happening here

425
00:18:48,500 --> 00:18:57,680
it recalibrated after I disconnected

426
00:18:51,390 --> 00:18:57,680
sorry yeah it's fine we're patient

427
00:19:07,140 --> 00:19:11,460
somebody needs to sing the jeopardy tune

428

00:19:11,549 --> 00:19:15,309

okay

429

00:19:12,759 --> 00:19:19,599

so with any luck I'll be able to tell

430

00:19:15,309 --> 00:19:24,519

you a little something about the plumes

431

00:19:19,599 --> 00:19:26,199

on Europa water ice life which is a

432

00:19:24,519 --> 00:19:32,200

little bit like our Baltimore winter

433

00:19:26,200 --> 00:19:34,900

this year let's see which way does this

434

00:19:32,200 --> 00:19:39,789

go so this is the abstract that I put

435

00:19:34,900 --> 00:19:43,740

together but more importantly is there

436

00:19:39,789 --> 00:19:45,700

are lots of people working on

437

00:19:43,740 --> 00:19:49,089

understanding what's going on with

438

00:19:45,700 --> 00:19:52,900

Europa in advance of perhaps actually

439

00:19:49,089 --> 00:19:54,220

sending a dedicated mission and I was

440

00:19:52,900 --> 00:19:56,590

trying to play around to figure but this

441

00:19:54,220 --> 00:19:58,120

was team a or team B or the raw team or

442

00:19:56,589 --> 00:20:00,039

the sparks team and I gave up on that

443

00:19:58,119 --> 00:20:03,519

because people go back and forth and

444

00:20:00,039 --> 00:20:05,409

people talk to each other so there I'm

445

00:20:03,519 --> 00:20:08,490

sure that I laughs I inadvertently might

446

00:20:05,410 --> 00:20:11,830

have left off some people but I

447

00:20:08,490 --> 00:20:15,490

apologize if I did that so more

448

00:20:11,829 --> 00:20:18,250

importantly is as an observer probably

449

00:20:15,490 --> 00:20:20,319

not tonight but maybe when it's clear if

450

00:20:18,250 --> 00:20:22,660

you go out and they look in the

451

00:20:20,319 --> 00:20:26,289

southeast kind of find where the moon is

452

00:20:22,660 --> 00:20:28,630

and you will see Jupiter and so

453

00:20:26,289 --> 00:20:31,440

Jupiter's a planet as you all know that

454

00:20:28,630 --> 00:20:34,600

we've known since antiquity when our

455

00:20:31,440 --> 00:20:36,759

ancestors first became Homo sapiens I am

456

00:20:34,599 --> 00:20:45,089

sure they looked up and saw Jupiter and

457
00:20:36,759 --> 00:20:49,930
named it something and 400 years ago in

458
00:20:45,089 --> 00:20:51,939
1609 Galileo as we know in I wouldn't

459
00:20:49,930 --> 00:20:54,450
say he invented the telescope but he was

460
00:20:51,940 --> 00:20:56,980
one of the first to put it together and

461
00:20:54,450 --> 00:20:59,769
incidentally he was very ill he had like

462
00:20:56,980 --> 00:21:01,210
the flu or something when he was putting

463
00:20:59,769 --> 00:21:03,879
together at the telescope

464
00:21:01,210 --> 00:21:07,480
I guess he kept him from being too sick

465
00:21:03,880 --> 00:21:11,920
and later he turned that telescope and

466
00:21:07,480 --> 00:21:13,599
he was the first to point at a celestial

467
00:21:11,920 --> 00:21:15,800
object and in his case it was Jupiter

468
00:21:13,599 --> 00:21:20,119
and what he saw over

469
00:21:15,799 --> 00:21:24,609
a period of time were a series of moons

470
00:21:20,119 --> 00:21:27,829
or objects or little stars that were

471
00:21:24,609 --> 00:21:29,659
revolving or moving around Jupiter and

472
00:21:27,829 --> 00:21:31,789
this is just a blow-up of that letter

473
00:21:29,660 --> 00:21:36,350
that I showed which is a letter he wrote

474
00:21:31,789 --> 00:21:39,079
to the Doge a of Venice in 1610 and he

475
00:21:36,349 --> 00:21:44,629
in that letter he is describing his

476
00:21:39,079 --> 00:21:50,899
observations so 1609 first observations

477
00:21:44,630 --> 00:21:52,940
of Europa and if I can do this I will

478
00:21:50,900 --> 00:21:58,730
start the movie because this is kind of

479
00:21:52,940 --> 00:22:02,120
cute I love the Internet this is a movie

480
00:21:58,730 --> 00:22:05,000
that put together by a gentleman named I

481
00:22:02,119 --> 00:22:07,729
think somebody right he has a website

482
00:22:05,000 --> 00:22:10,849
he's a computer scientist by profession

483
00:22:07,730 --> 00:22:13,880
and what he did is he took all of the

484
00:22:10,849 --> 00:22:17,629
observations that Galileo had recorded

485

00:22:13,880 --> 00:22:20,870
and he's juxtaposed those on a on the

486
00:22:17,630 --> 00:22:23,450
ephemeris and so what you see now is the

487
00:22:20,869 --> 00:22:25,459
beautiful pictures on the top and then

488
00:22:23,450 --> 00:22:26,900
Galileo's observations on the bottom

489
00:22:25,460 --> 00:22:32,000
this is just sort of a fun little thing

490
00:22:26,900 --> 00:22:36,200
and it'll go through sort of the modern

491
00:22:32,000 --> 00:22:39,259
and the end the ancient ok so let's just

492
00:22:36,200 --> 00:22:42,440
put this in context a little bit when we

493
00:22:39,259 --> 00:22:44,359
talk about the moons it's you know it's

494
00:22:42,440 --> 00:22:47,539
natural to think of it as being like our

495
00:22:44,359 --> 00:22:50,719
moon so here's our moon here this is

496
00:22:47,539 --> 00:22:53,329
Europa and it's about the same size over

497
00:22:50,720 --> 00:22:55,549
here so that's kind of comforting Moon's

498
00:22:53,329 --> 00:22:59,859
can be the same size as our Moon this is

499
00:22:55,549 --> 00:23:02,329

Callisto Ganymede Europa and IO or IO

500

00:22:59,859 --> 00:23:04,609

the four Galilean moons of although

501

00:23:02,329 --> 00:23:06,079

Galileo called and the Medici moons as

502

00:23:04,609 --> 00:23:10,279

you remember because the Medici was

503

00:23:06,079 --> 00:23:13,909

where his patrons it's always good to

504

00:23:10,279 --> 00:23:17,359

keep your patrons happy anyway so here's

505

00:23:13,910 --> 00:23:19,040

Europa tis not the largest of Jupiter's

506

00:23:17,359 --> 00:23:21,259

moons but it is certainly one of the

507

00:23:19,039 --> 00:23:23,029

most interesting along with you and neo

508

00:23:21,259 --> 00:23:25,849

is known to have volcanic activity and

509

00:23:23,029 --> 00:23:27,740

just for fun and scale here's one of the

510

00:23:25,849 --> 00:23:29,240

bands on Jupiter so you get the sense

511

00:23:27,740 --> 00:23:29,630

that these are actually relatively small

512

00:23:29,240 --> 00:23:34,730

and

513

00:23:29,630 --> 00:23:36,500

jupiter is very very big so we will skip

514
00:23:34,730 --> 00:23:39,410
forward a few hundred years to the

515
00:23:36,500 --> 00:23:43,160
Voyager missions and the Voyager I think

516
00:23:39,410 --> 00:23:46,480
are the most successful missions in my

517
00:23:43,160 --> 00:23:50,330
view that NASA has put together they

518
00:23:46,480 --> 00:23:52,910
have been going through the solar system

519
00:23:50,329 --> 00:23:55,189
for over 30 approaching 40 years

520
00:23:52,910 --> 00:23:58,040
returning good data ever since and it

521
00:23:55,190 --> 00:24:00,920
this was one of the first images that we

522
00:23:58,039 --> 00:24:03,829
had close-up images that we had of

523
00:24:00,920 --> 00:24:06,460
Jupiter and its moons this over here is

524
00:24:03,829 --> 00:24:08,689
a o and this is Europa down here

525
00:24:06,460 --> 00:24:11,000
question and these little dots are just

526
00:24:08,690 --> 00:24:14,269
some fiducial marks on the imaging

527
00:24:11,000 --> 00:24:16,460
system of Voyager about 20 years later

528
00:24:14,269 --> 00:24:18,470
there was another mission this time

529
00:24:16,460 --> 00:24:22,160
called the Galileo mission which also

530
00:24:18,470 --> 00:24:24,049
went to Jupiter and what I think is

531
00:24:22,160 --> 00:24:27,590
remarkable and a lot of people have as

532
00:24:24,049 --> 00:24:30,169
well is that we see Europa this was

533
00:24:27,589 --> 00:24:34,250
taken about I don't know almost six

534
00:24:30,170 --> 00:24:36,140
sixty thousand miles away is that Europe

535
00:24:34,250 --> 00:24:37,789
is relatively smooth it doesn't have big

536
00:24:36,140 --> 00:24:39,370
huge craters it doesn't have big huge

537
00:24:37,789 --> 00:24:42,230
mountains and it's got all these little

538
00:24:39,369 --> 00:24:45,579
striations all over it and some dark

539
00:24:42,230 --> 00:24:47,990
spots so it's a very interesting moon

540
00:24:45,579 --> 00:24:50,750
it's an interesting object in and of

541
00:24:47,990 --> 00:24:53,930
itself and this is a beautiful image

542

00:24:50,750 --> 00:24:58,779
that got reprocessed in the imaging

543
00:24:53,930 --> 00:25:03,259
department by somebody so to highlight

544
00:24:58,779 --> 00:25:05,720
the striations and sort of false color

545
00:25:03,259 --> 00:25:09,529
images and what you see is that these

546
00:25:05,720 --> 00:25:13,370
look like cracks in the ice fissures in

547
00:25:09,529 --> 00:25:17,299
the ice which tells you something about

548
00:25:13,369 --> 00:25:19,729
what is going on in on the moon and this

549
00:25:17,299 --> 00:25:22,730
is a blow-up also from the Galileo

550
00:25:19,730 --> 00:25:25,279
spacecraft where you can see these

551
00:25:22,730 --> 00:25:27,799
cracks and fissures and apparently some

552
00:25:25,279 --> 00:25:29,000
deposits of material because it's not

553
00:25:27,799 --> 00:25:33,440
all white and icy

554
00:25:29,000 --> 00:25:35,569
so this points to and there been a lot

555
00:25:33,440 --> 00:25:38,600
of papers and people got really busy and

556
00:25:35,569 --> 00:25:42,750

said this this looks a lot like cracking

557

00:25:38,599 --> 00:25:44,669

of ice and maybe it looks like looks

558

00:25:42,750 --> 00:25:48,059

like plate tectonics like we have on

559

00:25:44,670 --> 00:25:50,250

earth the the continental crusts and our

560

00:25:48,059 --> 00:25:53,129

shifting around in subducting and

561

00:25:50,250 --> 00:25:57,119

separating in this case this is on the

562

00:25:53,130 --> 00:26:00,900

icy surface so it's a very very

563

00:25:57,119 --> 00:26:03,000

intriguing but in addition one of the

564

00:26:00,900 --> 00:26:05,310

things that the Galileo spacecraft had

565

00:26:03,000 --> 00:26:06,990

with it was a magnetometer so it was

566

00:26:05,309 --> 00:26:11,369

measuring the magnetic field around

567

00:26:06,990 --> 00:26:15,079

Jupiter and an interesting thing is that

568

00:26:11,369 --> 00:26:17,429

if you have another source of

569

00:26:15,079 --> 00:26:19,230

electromagnetism it's sort of like

570

00:26:17,430 --> 00:26:20,850

having two magnets if you try to put the

571
00:26:19,230 --> 00:26:24,120
two South Poles together you get a

572
00:26:20,849 --> 00:26:26,429
little deflection have you ever tried

573
00:26:24,119 --> 00:26:28,139
that when you were kids so you'd see

574
00:26:26,430 --> 00:26:29,640
something similar if you had another

575
00:26:28,140 --> 00:26:31,560
source nearby you would see a little

576
00:26:29,640 --> 00:26:34,340
deflection in the magnetic field

577
00:26:31,559 --> 00:26:36,329
so when gyro PI was passing through

578
00:26:34,339 --> 00:26:40,789
Jupiter's magnetic field the

579
00:26:36,329 --> 00:26:43,919
magnetometer detected a deflection and

580
00:26:40,789 --> 00:26:46,109
that deflection was consistent with it

581
00:26:43,920 --> 00:26:48,509
another conductive or an inductive body

582
00:26:46,109 --> 00:26:52,799
and it probably had to be something like

583
00:26:48,509 --> 00:26:55,109
slushy salty water because it had to be

584
00:26:52,799 --> 00:26:56,730
something that was globally connected he

585
00:26:55,109 --> 00:26:58,889
couldn't just have one little pond it

586
00:26:56,730 --> 00:27:00,450
had to be all all around and about the

587
00:26:58,890 --> 00:27:06,270
only thing people could think of at the

588
00:27:00,450 --> 00:27:08,190
time was some slushy icy material which

589
00:27:06,269 --> 00:27:11,759
of course makes things really really

590
00:27:08,190 --> 00:27:14,910
interesting because now we have ice on

591
00:27:11,759 --> 00:27:21,359
this planet and potentially also water

592
00:27:14,910 --> 00:27:23,160
and so this is a sort of a model of what

593
00:27:21,359 --> 00:27:25,349
this might look like here's the the

594
00:27:23,160 --> 00:27:28,019
water down here some kind of a thick

595
00:27:25,349 --> 00:27:31,589
warm ice shelf and here you can see the

596
00:27:28,019 --> 00:27:34,349
cracks on the top subducting just like

597
00:27:31,589 --> 00:27:36,659
they would on on earth Stevie had plate

598
00:27:34,349 --> 00:27:39,359
tectonics and we're there little soft

599

00:27:36,660 --> 00:27:41,130
spots you might see sort of cryo lavas

600
00:27:39,359 --> 00:27:45,119
so instead of being molten lava I would

601
00:27:41,130 --> 00:27:48,450
be molten water otherwise known as

602
00:27:45,119 --> 00:27:50,519
liquid water and this would be something

603
00:27:48,450 --> 00:27:52,440
that would build up over time and the

604
00:27:50,519 --> 00:27:54,539
other clue to this is that was because

605
00:27:52,440 --> 00:27:56,160
the surface of Europa is so smooth it

606
00:27:54,539 --> 00:27:58,379
doesn't have a lot of cratering what

607
00:27:56,160 --> 00:28:00,180
also indicates it's a young surface and

608
00:27:58,380 --> 00:28:02,220
the only way you get a young surface is

609
00:28:00,180 --> 00:28:04,500
if you have some regeneration of

610
00:28:02,220 --> 00:28:08,670
material that covers the cracks and the

611
00:28:04,500 --> 00:28:10,170
in the craters so this is all pretty

612
00:28:08,670 --> 00:28:14,220
fascinating and people got really

613
00:28:10,170 --> 00:28:15,900

intrigued but this wasn't really enough

614

00:28:14,220 --> 00:28:20,190

to answer the question because you could

615

00:28:15,900 --> 00:28:25,710

still imagine having a rocky core in the

616

00:28:20,190 --> 00:28:30,480

planet ice warm ice and then cold ice on

617

00:28:25,710 --> 00:28:34,890

the surface or maybe you had a rocky

618

00:28:30,480 --> 00:28:39,089

interior and then a water layer down

619

00:28:34,890 --> 00:28:41,670

here and then ice and this was something

620

00:28:39,089 --> 00:28:44,039

in play if you have a lot of ice it's

621

00:28:41,670 --> 00:28:47,220

probably not so interesting or maybe it

622

00:28:44,039 --> 00:28:49,619

is but if you have water now you start

623

00:28:47,220 --> 00:28:51,839

thinking could you possibly have

624

00:28:49,619 --> 00:28:56,519

something really interesting going on if

625

00:28:51,839 --> 00:28:57,990

you have water and the answer of course

626

00:28:56,519 --> 00:29:00,569

and what we're working up to is if you

627

00:28:57,990 --> 00:29:02,789

have water then you have life or you

628
00:29:00,569 --> 00:29:07,319
have the possibility of life but the one

629
00:29:02,789 --> 00:29:10,859
question is Europa is far away it's very

630
00:29:07,319 --> 00:29:13,579
far from from the Sun it's and you have

631
00:29:10,859 --> 00:29:17,759
this icy cover so how would you get

632
00:29:13,579 --> 00:29:21,329
heating of the material to in order to

633
00:29:17,759 --> 00:29:23,339
have a liquid water ocean and so one

634
00:29:21,329 --> 00:29:25,379
potential answer and this is probably

635
00:29:23,339 --> 00:29:28,769
the right one is something called tidal

636
00:29:25,380 --> 00:29:32,070
heating and what that does is as as as

637
00:29:28,769 --> 00:29:33,930
Europa goes around Jupiter it's not in a

638
00:29:32,069 --> 00:29:37,829
perfectly circular orbit so you have

639
00:29:33,930 --> 00:29:39,930
gravitational forces acting on the moon

640
00:29:37,829 --> 00:29:41,429
itself sort of pushing and pulling it

641
00:29:39,930 --> 00:29:43,500
you can think of it as either you know

642
00:29:41,430 --> 00:29:45,240
and you bend a spoon you get a little

643
00:29:43,500 --> 00:29:47,700
heat or you're stretching a rubber band

644
00:29:45,240 --> 00:29:49,740
and you feel it it gets a little hot so

645
00:29:47,700 --> 00:29:52,940
sort of like friction and that is

646
00:29:49,740 --> 00:30:01,799
probably the source of the heat that

647
00:29:52,940 --> 00:30:03,960
keeps the water liquid then the Galileo

648
00:30:01,799 --> 00:30:07,019
mission I think has given planetary

649
00:30:03,960 --> 00:30:09,819
astronomers a lot to work on but I think

650
00:30:07,019 --> 00:30:13,059
it's it's been about 30 years and we're

651
00:30:09,819 --> 00:30:17,500
about you for NASA guys if you hear me

652
00:30:13,059 --> 00:30:22,059
were about you for another mission so

653
00:30:17,500 --> 00:30:24,160
this is a particular region on Europe

654
00:30:22,059 --> 00:30:26,019
and you can see the striations there

655
00:30:24,160 --> 00:30:27,960
this region is highlighted and this is

656

00:30:26,019 --> 00:30:32,379
now work that comes from a British

657
00:30:27,960 --> 00:30:33,850
Schmidt who's been working on this on

658
00:30:32,380 --> 00:30:36,610
Europa since she was I think in grad

659
00:30:33,849 --> 00:30:39,459
school and what this shows is a region

660
00:30:36,609 --> 00:30:41,289
that it looks very chaotic it looks sort

661
00:30:39,460 --> 00:30:43,930
of crumpled II like something happened

662
00:30:41,289 --> 00:30:45,730
there it's not a it's not a crater some

663
00:30:43,930 --> 00:30:48,519
typical crater has a little cone shape

664
00:30:45,730 --> 00:30:50,349
and you see the material inside but this

665
00:30:48,519 --> 00:30:54,279
seems to indicate that there might have

666
00:30:50,349 --> 00:30:58,779
been a region on the planet I mean on

667
00:30:54,279 --> 00:31:03,730
the moon that might be the source of

668
00:30:58,779 --> 00:31:06,789
some kind of flow of material a crack in

669
00:31:03,730 --> 00:31:09,250
the ice raises a material and so there

670
00:31:06,789 --> 00:31:11,619

was she developed a model that seemed to

671

00:31:09,250 --> 00:31:15,960

indicate that you had to have some kind

672

00:31:11,619 --> 00:31:25,089

of water driving this type of feature

673

00:31:15,960 --> 00:31:29,350

liquid and Galileo get to the rescue

674

00:31:25,089 --> 00:31:32,169

again and one of the John Spencer

675

00:31:29,349 --> 00:31:34,269

studied the thermal mapping of Europa

676

00:31:32,170 --> 00:31:36,009

and just because even you want to know

677

00:31:34,269 --> 00:31:38,529

what's going on what's the temperature

678

00:31:36,009 --> 00:31:39,910

on the surface is it all one the same

679

00:31:38,529 --> 00:31:41,710

temperature all around is there

680

00:31:39,910 --> 00:31:43,330

variation in the temperatures at hot

681

00:31:41,710 --> 00:31:46,480

cold is it like that the Earth's where

682

00:31:43,329 --> 00:31:49,659

the poles are colder etc and so he did

683

00:31:46,480 --> 00:31:50,980

this heat map if you will it measured

684

00:31:49,660 --> 00:31:52,690

the temperature in various locations

685
00:31:50,980 --> 00:31:54,940
this is sort of at the South Pole this

686
00:31:52,690 --> 00:31:57,460
is sort of hot you have regions where

687
00:31:54,940 --> 00:32:01,019
you go from warm relatively warm to cold

688
00:31:57,460 --> 00:32:04,180
and these are degrees um I think Kelvin

689
00:32:01,019 --> 00:32:07,900
so this also tells us that it's not as

690
00:32:04,180 --> 00:32:12,029
solidly single temperature situation

691
00:32:07,900 --> 00:32:14,680
which just adds to the to the intrigue

692
00:32:12,029 --> 00:32:18,129
so this is an a bit of an artist

693
00:32:14,680 --> 00:32:20,560
conception I think that between Galilean

694
00:32:18,130 --> 00:32:22,720
Voyager and a lot of heavy lifting by

695
00:32:20,559 --> 00:32:23,049
planetary scientists we sort of came up

696
00:32:22,720 --> 00:32:25,059
with

697
00:32:23,049 --> 00:32:27,579
the idea that we had a salty liquid

698
00:32:25,059 --> 00:32:30,009
ocean and that potentially you could

699
00:32:27,579 --> 00:32:33,039
have some kind of geyser activity if you

700
00:32:30,009 --> 00:32:34,930
had liquid water depositing here's sort

701
00:32:33,039 --> 00:32:36,940
of one of those little chaos terrains

702
00:32:34,930 --> 00:32:38,500
like the one I showed you earlier pool

703
00:32:36,940 --> 00:32:40,630
of water underneath this is probably

704
00:32:38,500 --> 00:32:42,069
some thin layer of ice about a hundred

705
00:32:40,630 --> 00:32:43,870
kilometers thick you get a little water

706
00:32:42,069 --> 00:32:49,569
pooling up and it comes up and maybe you

707
00:32:43,869 --> 00:32:51,849
could see geysers and so this seems to

708
00:32:49,569 --> 00:32:54,879
indicate all that it seems to indicate

709
00:32:51,849 --> 00:32:58,299
that this is really the right idea the

710
00:32:54,880 --> 00:33:01,330
right model for Europa so you do have a

711
00:32:58,299 --> 00:33:03,879
liquid ocean a salty liquid water ocean

712
00:33:01,329 --> 00:33:11,339
underneath ice and now things get really

713

00:33:03,880 --> 00:33:14,830
interesting because this is not Europa

714
00:33:11,339 --> 00:33:20,589
this is Enceladus which is a moon of

715
00:33:14,829 --> 00:33:22,839
Saturn and Cassini which was not did not

716
00:33:20,589 --> 00:33:25,929
go up 40 years ago more recently than

717
00:33:22,839 --> 00:33:30,899
that took a picture of Enceladus and

718
00:33:25,930 --> 00:33:40,330
noticed that there was water vapor on

719
00:33:30,900 --> 00:33:43,740
the South Pole hmm so if Cassini has

720
00:33:40,329 --> 00:33:50,649
this what about Europa

721
00:33:43,740 --> 00:33:54,660
so if Europa also has plumes of water

722
00:33:50,650 --> 00:33:58,060
vapor then maybe we can learn something

723
00:33:54,660 --> 00:34:00,009
about its ocean without necessarily

724
00:33:58,059 --> 00:34:01,720
having to go and send a mission and do

725
00:34:00,009 --> 00:34:05,400
ice cores and drill down a hundred

726
00:34:01,720 --> 00:34:05,400
kilometres into the ice

727
00:34:07,259 --> 00:34:14,019

so this is where Hubble comes in so and

728

00:34:12,039 --> 00:34:19,090

this is work that started roughly around

729

00:34:14,019 --> 00:34:21,969

2010 so this is Lorenz Roth it all came

730

00:34:19,090 --> 00:34:26,130

up with one technique and it's called

731

00:34:21,969 --> 00:34:26,129

spectral imaging and I wasn't there

732

00:34:26,219 --> 00:34:31,019

which is not the same thing as direct

733

00:34:28,809 --> 00:34:34,599

imaging so we think of a spectrum as

734

00:34:31,019 --> 00:34:36,800

white light coming through a prism or a

735

00:34:34,599 --> 00:34:38,750

dispersing piece of glass and then

736

00:34:36,800 --> 00:34:41,390

getting broken up into its constituent

737

00:34:38,750 --> 00:34:44,150

colors we've all seen that or a drop of

738

00:34:41,389 --> 00:34:47,449

water or your hose or the rainbows they

739

00:34:44,150 --> 00:34:51,079

all work the same way and if you

740

00:34:47,449 --> 00:34:52,669

remember from your physics class whether

741

00:34:51,079 --> 00:34:54,619

it was high school or college or a

742
00:34:52,670 --> 00:34:58,159
graduate school or maybe even last week

743
00:34:54,619 --> 00:35:00,289
and you're analyzing some data typically

744
00:34:58,159 --> 00:35:02,449
when we do spectroscopy we talk about

745
00:35:00,289 --> 00:35:04,219
having a slit and then you have the

746
00:35:02,449 --> 00:35:07,579
disperser in this case it's a prism and

747
00:35:04,219 --> 00:35:09,679
this is just a model it gets sent off

748
00:35:07,579 --> 00:35:13,279
collimated and what you see then is a

749
00:35:09,679 --> 00:35:17,589
bunch of lines either absorption lines

750
00:35:13,280 --> 00:35:20,240
in this case or emission lines and

751
00:35:17,590 --> 00:35:23,240
that's a normal way of doing things but

752
00:35:20,239 --> 00:35:29,569
in actuality what these little lines are

753
00:35:23,239 --> 00:35:34,729
are actually an image of the slit so

754
00:35:29,570 --> 00:35:38,269
what happens if you take a moon and you

755
00:35:34,730 --> 00:35:40,760
use your traditional small slit well you

756
00:35:38,269 --> 00:35:43,489
can't see the whole moon but if you make

757
00:35:40,760 --> 00:35:48,110
the slit bigger and fortunately Hubble

758
00:35:43,489 --> 00:35:50,569
is one of Hubble's instruments the Space

759
00:35:48,110 --> 00:35:53,000
Telescope imaging spectrograph has a

760
00:35:50,570 --> 00:35:56,750
slit that's about two arc seconds wide

761
00:35:53,000 --> 00:36:00,710
and Europa extends an angle of about one

762
00:35:56,750 --> 00:36:03,349
in a bit so you open up the slit and you

763
00:36:00,710 --> 00:36:05,329
go through your same system so this is

764
00:36:03,349 --> 00:36:08,420
now standing in for the entire set of

765
00:36:05,329 --> 00:36:11,719
optics that are complicated and what you

766
00:36:08,420 --> 00:36:13,849
get is an image that's no longer those

767
00:36:11,719 --> 00:36:16,009
straight lines but rather an image of

768
00:36:13,849 --> 00:36:22,369
the source because you've made the slit

769
00:36:16,010 --> 00:36:24,890
large enough and then the idea then is

770

00:36:22,369 --> 00:36:27,309
that we know that if there is a plume of

771
00:36:24,889 --> 00:36:31,069
water when water hits the atmosphere

772
00:36:27,309 --> 00:36:33,230
water's hydrogen h₂o two hydrogen's and

773
00:36:31,070 --> 00:36:35,480
an oxygen when it reaches the atmosphere

774
00:36:33,230 --> 00:36:37,969
will dissociate or exits the atmosphere

775
00:36:35,480 --> 00:36:40,460
it will dissociate break apart into

776
00:36:37,969 --> 00:36:43,189
hydrogen and oxygen so the logical thing

777
00:36:40,460 --> 00:36:45,440
to do would then be to look for the

778
00:36:43,190 --> 00:36:48,289
dissociation products of water which are

779
00:36:45,440 --> 00:36:50,220
hydrogen and oxygen and in the

780
00:36:48,289 --> 00:36:53,369
ultraviolet there are two

781
00:36:50,219 --> 00:36:56,159
of hydrogen and oxygen and this is what

782
00:36:53,369 --> 00:37:00,960
Lorenz Roth and his team took advantage

783
00:36:56,159 --> 00:37:03,389
of and so in 1999 this is the series of

784
00:37:00,960 --> 00:37:06,809

images this is this is the hydrogen

785

00:37:03,389 --> 00:37:11,039

lines these are the oxygen lines in 2012

786

00:37:06,809 --> 00:37:13,650

they took another series of images but

787

00:37:11,039 --> 00:37:17,039

in December of 2012 when they saw those

788

00:37:13,650 --> 00:37:19,139

images what they noticed is that unlike

789

00:37:17,039 --> 00:37:22,679

the earlier images there was a little

790

00:37:19,139 --> 00:37:28,049

excess of both hydrogen and oxygen down

791

00:37:22,679 --> 00:37:31,069

here and that indicates that there was a

792

00:37:28,050 --> 00:37:35,280

plume and they wrote a paper in science

793

00:37:31,070 --> 00:37:38,420

which is here came out in 2014 there

794

00:37:35,280 --> 00:37:41,490

were subsequent observations almost 17

795

00:37:38,420 --> 00:37:43,710

detection our orbits Lee and there were

796

00:37:41,489 --> 00:37:47,269

no additional plumes discovered so now

797

00:37:43,710 --> 00:37:49,230

that Lucknow just like with the

798

00:37:47,269 --> 00:37:51,150

presentation earlier is this the data

799
00:37:49,230 --> 00:37:53,519
did we use you know everybody thinks did

800
00:37:51,150 --> 00:37:55,650
we screw something up what's going on

801
00:37:53,519 --> 00:37:58,230
that we don't see it again get really

802
00:37:55,650 --> 00:38:00,150
panicky you think you've done something

803
00:37:58,230 --> 00:38:02,460
wrong in the analysis and you go back

804
00:38:00,150 --> 00:38:07,889
you do the reanalysis it's like no this

805
00:38:02,460 --> 00:38:10,769
was correct that really but because they

806
00:38:07,889 --> 00:38:13,049
didn't see the plumes again there was

807
00:38:10,769 --> 00:38:14,699
already hints that Europa could not be

808
00:38:13,050 --> 00:38:20,670
like Enceladus and so this is very

809
00:38:14,699 --> 00:38:23,069
regular cryovolcanism if you will so if

810
00:38:20,670 --> 00:38:25,230
you wanted to get a pretty picture and

811
00:38:23,070 --> 00:38:30,470
put it together so this is the location

812
00:38:25,230 --> 00:38:34,380
of the plumes and then here is um Europa

813
00:38:30,469 --> 00:38:35,969
okay the other thing about science is

814
00:38:34,380 --> 00:38:39,539
that you like people to repeat your

815
00:38:35,969 --> 00:38:41,549
experiment in some other way so that you

816
00:38:39,539 --> 00:38:44,309
have some confidence of what you're

817
00:38:41,550 --> 00:38:47,070
doing so the second method was to

818
00:38:44,309 --> 00:38:48,630
actually use direct imaging so no longer

819
00:38:47,070 --> 00:38:49,890
using spectrograph but just direct

820
00:38:48,630 --> 00:38:51,869
imaging just like you do with your

821
00:38:49,889 --> 00:38:53,389
camera and take a picture of somebody or

822
00:38:51,869 --> 00:38:56,750
the tree or the Pussycats

823
00:38:53,389 --> 00:39:01,289
okay that's direct imaging in this case

824
00:38:56,750 --> 00:39:02,880
there have been an example in 2000 John

825
00:39:01,289 --> 00:39:05,130
Spencer had looked at he

826
00:39:02,880 --> 00:39:07,019
in the ultraviolet so this is e oh and

827

00:39:05,130 --> 00:39:08,190
this is Jupiter in the background you

828
00:39:07,019 --> 00:39:11,969
can see there's a little plume here

829
00:39:08,190 --> 00:39:15,920
remember yo really is volcanic and so

830
00:39:11,969 --> 00:39:19,250
the idea was that look if this worked

831
00:39:15,920 --> 00:39:23,900
for IO where you can have Jupiter

832
00:39:19,250 --> 00:39:26,159
effectively back light so you're seeing

833
00:39:23,900 --> 00:39:28,200
Jupiter in the back back lighting the

834
00:39:26,159 --> 00:39:29,969
atmosphere of the of the of the of the

835
00:39:28,199 --> 00:39:31,649
moon the tenuous atmosphere if there's

836
00:39:29,969 --> 00:39:37,169
anything going on you should be able to

837
00:39:31,650 --> 00:39:39,180
detect it so the second idea then was to

838
00:39:37,170 --> 00:39:42,150
do direct imaging in the farl travaille

839
00:39:39,179 --> 00:39:44,009
ilat around 150 hundred and 60

840
00:39:42,150 --> 00:39:47,599
nanometers this is a region that is of

841
00:39:44,010 --> 00:39:51,720

course not accessible from the ground

842

00:39:47,599 --> 00:39:55,230

and we took images for almost three

843

00:39:51,719 --> 00:39:57,929

years well two years and we had 12

844

00:39:55,230 --> 00:39:59,250

images of Europa in transit and what we

845

00:39:57,929 --> 00:40:02,809

were doing then was measuring the

846

00:39:59,250 --> 00:40:05,820

atmosphere not necessarily looking for

847

00:40:02,809 --> 00:40:07,980

Jets but just changes in the in the in

848

00:40:05,820 --> 00:40:09,960

the thickness or the opacity of the

849

00:40:07,980 --> 00:40:11,639

atmosphere and we also just to

850

00:40:09,960 --> 00:40:13,320

double-check had images taken out of

851

00:40:11,639 --> 00:40:18,210

transit just in case I had something to

852

00:40:13,320 --> 00:40:21,360

do is being in front of Jupiter and the

853

00:40:18,210 --> 00:40:23,099

analysis of this data was is pretty

854

00:40:21,360 --> 00:40:24,960

straightforward here's the real image of

855

00:40:23,099 --> 00:40:27,059

Europa and this is Jupiter in the

856
00:40:24,960 --> 00:40:28,409
background and what you want to make

857
00:40:27,059 --> 00:40:30,630
sure is that that when you do the

858
00:40:28,409 --> 00:40:32,099
subtraction in R the analysis of the

859
00:40:30,630 --> 00:40:32,789
image that you're not doing anything

860
00:40:32,099 --> 00:40:35,099
crazy

861
00:40:32,789 --> 00:40:38,039
so the standard thing to do is to say

862
00:40:35,099 --> 00:40:44,000
assume a circle with a and you assume

863
00:40:38,039 --> 00:40:46,559
some kind of illumination pattern you

864
00:40:44,000 --> 00:40:48,570
figure out what Jupiter looks like in

865
00:40:46,559 --> 00:40:52,170
the background you make a model and then

866
00:40:48,570 --> 00:40:53,880
you subtract the model you actually also

867
00:40:52,170 --> 00:40:55,260
have to add you know the effects of the

868
00:40:53,880 --> 00:40:57,690
instrument on your model so you

869
00:40:55,260 --> 00:40:59,220
basically you're making a fake image so

870
00:40:57,690 --> 00:41:03,470
here's the fake image and here's the

871
00:40:59,219 --> 00:41:05,789
real image and they look okay they look

872
00:41:03,469 --> 00:41:08,279
plausible this is one that doesn't have

873
00:41:05,789 --> 00:41:09,480
plumes and this one in the model doesn't

874
00:41:08,280 --> 00:41:11,760
have it either so this tells you

875
00:41:09,480 --> 00:41:14,070
something about the gives you some

876
00:41:11,760 --> 00:41:16,140
confidence that your method is actually

877
00:41:14,070 --> 00:41:18,600
going to work

878
00:41:16,139 --> 00:41:21,420
and then just for fun you're just what

879
00:41:18,599 --> 00:41:24,029
these images look like here because

880
00:41:21,420 --> 00:41:25,409
Jupiter moves now here's the fun part of

881
00:41:24,030 --> 00:41:27,210
doing planetary science which I hadn't

882
00:41:25,409 --> 00:41:29,299
quite appreciated until I started doing

883
00:41:27,210 --> 00:41:32,639
it myself is that everything moves

884

00:41:29,300 --> 00:41:34,789
Jupiter moves Europa moves the satellite

885
00:41:32,639 --> 00:41:36,809
moves so everything has to somehow work

886
00:41:34,789 --> 00:41:38,159
together and you have to decide whether

887
00:41:36,809 --> 00:41:41,279
you're going to track on the moon or

888
00:41:38,159 --> 00:41:44,579
Jupiter or both so this is what it looks

889
00:41:41,280 --> 00:41:47,280
like if you assume that Jupiter isn't

890
00:41:44,579 --> 00:41:49,400
moving and then here if you assume

891
00:41:47,280 --> 00:41:51,870
Europa isn't moving so here's Europa and

892
00:41:49,400 --> 00:41:56,940
here's a shadow and that there's a no

893
00:41:51,869 --> 00:41:59,940
lovely Aurora and then I have to UM show

894
00:41:56,940 --> 00:42:02,970
this because this is kind of fun if you

895
00:41:59,940 --> 00:42:04,500
put all the images together and you D

896
00:42:02,969 --> 00:42:08,279
rotate everything then you could make

897
00:42:04,500 --> 00:42:10,710
fun images that show you here's Europa

898
00:42:08,280 --> 00:42:12,060

yours you here's the Great Red Spot and

899

00:42:10,710 --> 00:42:15,420

obviously it's a partial them is because

900

00:42:12,059 --> 00:42:20,009

we're not imaging the whole of Jupiter's

901

00:42:15,420 --> 00:42:21,690

face so that's kind of fun and the

902

00:42:20,010 --> 00:42:25,080

reason we could do this is that one of

903

00:42:21,690 --> 00:42:28,590

the advantage of this disc spectrograph

904

00:42:25,079 --> 00:42:31,710

or imaging system is that you can

905

00:42:28,590 --> 00:42:33,809

actually take observations at what's

906

00:42:31,710 --> 00:42:37,079

called time tags so that the separation

907

00:42:33,809 --> 00:42:39,570

each each exposure is 0.125 seconds and

908

00:42:37,079 --> 00:42:41,429

you just can keep doing that so every

909

00:42:39,570 --> 00:42:43,230

tenth of a second you have a new image

910

00:42:41,429 --> 00:42:45,719

which is one of the things that lets you

911

00:42:43,230 --> 00:42:47,460

make these lovely movies but it also

912

00:42:45,719 --> 00:42:52,169

helps if you're trying to look for

913
00:42:47,460 --> 00:42:54,630
features and then you can also play some

914
00:42:52,170 --> 00:42:57,690
more with these images and this was made

915
00:42:54,630 --> 00:43:01,019
by Sean Lockwood who's also on the staff

916
00:42:57,690 --> 00:43:03,059
here and from the same data because the

917
00:43:01,019 --> 00:43:04,199
movies are kind of fun what's the point

918
00:43:03,059 --> 00:43:06,119
of doing this if you can't have fun so

919
00:43:04,199 --> 00:43:09,139
here you see the aurora which is kind of

920
00:43:06,119 --> 00:43:12,389
fun it changes with time and here is

921
00:43:09,139 --> 00:43:15,210
Europa so this is you know not not

922
00:43:12,389 --> 00:43:17,909
enhanced at all and then if you really

923
00:43:15,210 --> 00:43:19,800
want to see but again unenhanced so

924
00:43:17,909 --> 00:43:21,929
we'll just skip right right past this

925
00:43:19,800 --> 00:43:24,210
because the thing that's interesting is

926
00:43:21,929 --> 00:43:26,039
that what we're looking for is 3,000

927
00:43:24,210 --> 00:43:28,590
kilometers and this is Europa's north

928
00:43:26,039 --> 00:43:30,500
and then just to show you because you

929
00:43:28,590 --> 00:43:32,940
got to show the data

930
00:43:30,500 --> 00:43:34,409
I've talked a lot about it I've shown

931
00:43:32,940 --> 00:43:38,119
some pretty movies but I haven't shown

932
00:43:34,409 --> 00:43:45,690
you the data but you should always ask

933
00:43:38,119 --> 00:43:48,359
so these are the twelve ten of the

934
00:43:45,690 --> 00:43:51,210
twelve observations that we took and one

935
00:43:48,360 --> 00:43:53,130
two three four five actually one two and

936
00:43:51,210 --> 00:43:55,679
they're given in time so we started in

937
00:43:53,130 --> 00:43:59,940
twin December of 2013 through March of

938
00:43:55,679 --> 00:44:01,829
2015 and we did that whole careful

939
00:43:59,940 --> 00:44:04,950
analysis subtracting out the model

940
00:44:01,829 --> 00:44:08,159
making sure and you'll notice if you

941

00:44:04,949 --> 00:44:10,500
look carefully that there are only three

942
00:44:08,159 --> 00:44:12,420
of these images that should look that

943
00:44:10,500 --> 00:44:18,210
show something different three of these

944
00:44:12,420 --> 00:44:26,309
are not like the others and those are

945
00:44:18,210 --> 00:44:28,320
the plumes maybe okay and this is just a

946
00:44:26,309 --> 00:44:30,090
close-up and what these are done here is

947
00:44:28,320 --> 00:44:34,380
you subtract the model out and again you

948
00:44:30,090 --> 00:44:35,880
see the enhancement so I know that we

949
00:44:34,380 --> 00:44:37,500
had a lot of discussion because now we

950
00:44:35,880 --> 00:44:39,869
saw three-d-- we didn't see them

951
00:44:37,500 --> 00:44:41,969
sequentially and then we looked at the

952
00:44:39,869 --> 00:44:44,940
roth paper and it looked like they were

953
00:44:41,969 --> 00:44:46,889
in the same location and in addition we

954
00:44:44,940 --> 00:44:48,869
actually found a plume in a different

955
00:44:46,889 --> 00:44:52,980

location the other ones were down here

956

00:44:48,869 --> 00:44:55,909

in March of 2017 we actually found

957

00:44:52,980 --> 00:44:59,159

something a little Pucci thing over here

958

00:44:55,909 --> 00:45:02,460

that repeated again there so that that

959

00:44:59,159 --> 00:45:09,059

would be a second second plume that's

960

00:45:02,460 --> 00:45:10,710

really cool this is just more of the

961

00:45:09,059 --> 00:45:12,179

images and then just to prove that we

962

00:45:10,710 --> 00:45:15,599

weren't kidding ourselves we added

963

00:45:12,179 --> 00:45:17,279

subtracted and convinced ourselves that

964

00:45:15,599 --> 00:45:24,179

that was right so where are these plumes

965

00:45:17,280 --> 00:45:26,820

found so the ones that the eight the the

966

00:45:24,179 --> 00:45:29,639

direct method the direct imaging method

967

00:45:26,820 --> 00:45:31,440

found right just north of the South Pole

968

00:45:29,639 --> 00:45:35,119

and then right here near this crater

969

00:45:31,440 --> 00:45:39,000

called quill and we saw it twice

970
00:45:35,119 --> 00:45:40,829
so the plume at will be repeated we saw

971
00:45:39,000 --> 00:45:42,989
that twice this one we've only seen once

972
00:45:40,829 --> 00:45:45,239
and this is the location

973
00:45:42,989 --> 00:45:49,199
of the plume as seen it with the

974
00:45:45,239 --> 00:45:49,979
spectroscopic method so we have one two

975
00:45:49,199 --> 00:45:53,969
three

976
00:45:49,980 --> 00:45:55,199
plumes if you count them and one of the

977
00:45:53,969 --> 00:45:57,000
things that's really need you've seen

978
00:45:55,199 --> 00:46:03,269
this image before cuz I showed it to you

979
00:45:57,000 --> 00:46:05,730
earlier is that here's well this region

980
00:46:03,269 --> 00:46:07,710
here is like two degrees warmer than the

981
00:46:05,730 --> 00:46:11,610
surrounding region and that's coincident

982
00:46:07,710 --> 00:46:14,460
with what with that repeating plume so

983
00:46:11,610 --> 00:46:17,039
the question we're asking is are they

984
00:46:14,460 --> 00:46:19,230
related is it possible that you could

985
00:46:17,039 --> 00:46:21,840
have a slight warming of the ice would

986
00:46:19,230 --> 00:46:24,150
that be enough to allow some liquid

987
00:46:21,840 --> 00:46:26,610
water to come through to sort of break

988
00:46:24,150 --> 00:46:32,460
through that's a it's intriguing we we

989
00:46:26,610 --> 00:46:35,460
don't know but it's a possibility and so

990
00:46:32,460 --> 00:46:38,579
this might be what that looks like that

991
00:46:35,460 --> 00:46:40,289
plume 100 rising 125 miles above the

992
00:46:38,579 --> 00:46:45,269
surface and of course there's a Jupiter

993
00:46:40,289 --> 00:46:53,279
in the background so um looks like there

994
00:46:45,269 --> 00:46:54,929
it's probably water on on Europa and the

995
00:46:53,280 --> 00:47:00,269
observations continue we didn't just

996
00:46:54,929 --> 00:47:02,009
stop in 2017 both groups have has

997
00:47:00,269 --> 00:47:03,750
amorphous as they are have are

998

00:47:02,010 --> 00:47:04,650
continuing their observations using

999
00:47:03,750 --> 00:47:08,400
different techniques and different

1000
00:47:04,650 --> 00:47:12,180
analysis methods so this is um from our

1001
00:47:08,400 --> 00:47:15,358
most recent 2017-2018 data taken with

1002
00:47:12,179 --> 00:47:18,149
the Hubble Space Telescope and again

1003
00:47:15,358 --> 00:47:20,699
it's really kind of fun to see them and

1004
00:47:18,150 --> 00:47:23,760
move around this is Ganymede up here by

1005
00:47:20,699 --> 00:47:26,129
the way that isn't just a splash you can

1006
00:47:23,760 --> 00:47:29,550
see you rope over there and you can see

1007
00:47:26,130 --> 00:47:35,849
that lovely I love the Aurora on the on

1008
00:47:29,550 --> 00:47:40,080
the poles of Jupiter okay so that's fun

1009
00:47:35,849 --> 00:47:44,400
there's a close-up of Ganymede so if you

1010
00:47:40,079 --> 00:47:47,519
have water we have ice we think we have

1011
00:47:44,400 --> 00:47:50,160
water the good thing is that both groups

1012
00:47:47,519 --> 00:47:53,809

got the same value when you do all your

1013

00:47:50,159 --> 00:47:53,809

calculations not only were the plumes

1014

00:47:54,590 --> 00:47:58,140

coincident so that the sparks

1015

00:47:56,639 --> 00:48:01,108

diamond arrived found one plume

1016

00:47:58,139 --> 00:48:04,379

coincident or near each other and we saw

1017

00:48:01,108 --> 00:48:08,940

one that repeated but we also determined

1018

00:48:04,380 --> 00:48:10,710

the amount of water based on the on the

1019

00:48:08,940 --> 00:48:12,088

images that the amount of water was

1020

00:48:10,710 --> 00:48:14,039

about the same so you don't get the same

1021

00:48:12,088 --> 00:48:16,679

numbers unless you're more or less on

1022

00:48:14,039 --> 00:48:20,010

the right track so now we have the

1023

00:48:16,679 --> 00:48:21,719

ingredients for life so we have so what

1024

00:48:20,010 --> 00:48:23,460

do you need you need atoms you need

1025

00:48:21,719 --> 00:48:27,409

molecules you need the most important

1026

00:48:23,460 --> 00:48:33,059

molecule of all h₂o and you need energy

1027
00:48:27,409 --> 00:48:38,239
now a nurse the energy that life as we

1028
00:48:33,059 --> 00:48:41,990
know it uses tens it comes from the Sun

1029
00:48:38,239 --> 00:48:46,679
plants the animals that eat the plants

1030
00:48:41,989 --> 00:48:50,278
algae slime mold bedbugs etc I'll derive

1031
00:48:46,679 --> 00:48:53,838
the energy required to synthesize these

1032
00:48:50,278 --> 00:48:56,329
elements into the amino acids along

1033
00:48:53,838 --> 00:48:58,980
biochemistry chain that happens

1034
00:48:56,329 --> 00:49:01,048
sometimes on earth we have hydrothermal

1035
00:48:58,980 --> 00:49:03,690
vents go to the bottom of the ocean

1036
00:49:01,048 --> 00:49:06,268
there are there's well volcanic activity

1037
00:49:03,690 --> 00:49:08,039
and that heats up the water and you get

1038
00:49:06,268 --> 00:49:11,038
these hydrothermal vents and we found

1039
00:49:08,039 --> 00:49:14,789
what we yeah and people have looked and

1040
00:49:11,039 --> 00:49:19,680
found at life bacteria and so forth

1041
00:49:14,789 --> 00:49:21,839
living there and this is a model sort of

1042
00:49:19,679 --> 00:49:24,328
indicating the tidal heating so if you

1043
00:49:21,838 --> 00:49:27,088
don't have direct energy from the Sun

1044
00:49:24,329 --> 00:49:29,670
and you may or may not have hydrothermal

1045
00:49:27,088 --> 00:49:32,538
vents you still need a source of energy

1046
00:49:29,670 --> 00:49:37,289
in order to be able to do the chemistry

1047
00:49:32,539 --> 00:49:40,200
that allows bio the biology to happen

1048
00:49:37,289 --> 00:49:42,569
and in Europa this is this would be due

1049
00:49:40,199 --> 00:49:51,419
to the tidal heating so there is an

1050
00:49:42,568 --> 00:49:54,500
energy source and many years of people

1051
00:49:51,420 --> 00:49:59,220
studying evolution so life on Earth is

1052
00:49:54,500 --> 00:50:02,400
divided into three clouds okay three

1053
00:49:59,219 --> 00:50:05,429
different groups we have what's what are

1054
00:50:02,400 --> 00:50:06,809
called the bacteria some of them we

1055

00:50:05,429 --> 00:50:09,219
don't like

1056
00:50:06,809 --> 00:50:10,690
these are single-celled generally

1057
00:50:09,219 --> 00:50:12,629
single-cell animals we have what's

1058
00:50:10,690 --> 00:50:16,059
called the archaea and those are

1059
00:50:12,630 --> 00:50:20,050
generally those those extremophiles

1060
00:50:16,059 --> 00:50:22,539
those organisms that like to live or

1061
00:50:20,050 --> 00:50:24,880
it's super salty super acidic super

1062
00:50:22,539 --> 00:50:28,989
alkaline super hot super cold super high

1063
00:50:24,880 --> 00:50:32,079
pressure super low pressure and then we

1064
00:50:28,989 --> 00:50:32,709
have the Eukarya and that's everything

1065
00:50:32,079 --> 00:50:36,309
else

1066
00:50:32,710 --> 00:50:42,760
this is slime molds bedbugs people cats

1067
00:50:36,309 --> 00:50:44,799
dogs your neighbor and I just put down

1068
00:50:42,760 --> 00:50:46,900
this last common ancestor because it's

1069
00:50:44,800 --> 00:50:49,269

kind of cool to see the quote unquote

1070

00:50:46,900 --> 00:50:51,280

Tree of Life if this one gets very messy

1071

00:50:49,269 --> 00:50:56,070

and so does this one so I just put

1072

00:50:51,280 --> 00:50:59,860

clouds but the main difference between

1073

00:50:56,070 --> 00:51:03,460

the left side and the right side is the

1074

00:50:59,860 --> 00:51:05,890

kind of cell that makes up the different

1075

00:51:03,460 --> 00:51:08,019

kinds of life and I have a question mark

1076

00:51:05,889 --> 00:51:13,119

for the viruses because I don't nobody

1077

00:51:08,019 --> 00:51:15,610

really knows where they fit in so these

1078

00:51:13,119 --> 00:51:19,989

guys have one particular kind of cell is

1079

00:51:15,610 --> 00:51:22,840

very simple and these organisms over

1080

00:51:19,989 --> 00:51:28,919

here do are all single-cell organisms

1081

00:51:22,840 --> 00:51:31,780

whereas as we know on this side whoa on

1082

00:51:28,920 --> 00:51:33,579

this side we have multicellular

1083

00:51:31,780 --> 00:51:35,950

organisms as well as single cellular

1084
00:51:33,579 --> 00:51:38,889
organisms and the cells are more

1085
00:51:35,949 --> 00:51:40,210
complicated how you know things like

1086
00:51:38,889 --> 00:51:41,679
that then you start getting into things

1087
00:51:40,210 --> 00:51:45,309
like how is the information for

1088
00:51:41,679 --> 00:51:47,440
replication or reproduction carried in

1089
00:51:45,309 --> 00:51:50,230
in the cells of different structures

1090
00:51:47,440 --> 00:51:57,010
that do that I think on this side the

1091
00:51:50,230 --> 00:51:59,079
eukaryotes over here on the right as you

1092
00:51:57,010 --> 00:52:01,270
can see these are real electronic

1093
00:51:59,079 --> 00:52:04,210
scanning electron images of these

1094
00:52:01,269 --> 00:52:07,150
critters so this cell has here's the

1095
00:52:04,210 --> 00:52:08,740
nucleus this is where the DNA lives all

1096
00:52:07,150 --> 00:52:09,880
the genetic information and you see they

1097
00:52:08,739 --> 00:52:11,219
have all these structures of

1098
00:52:09,880 --> 00:52:13,930
mitochondria furtive doing like

1099
00:52:11,219 --> 00:52:16,719
mitochondrial DNA analyses to see where

1100
00:52:13,929 --> 00:52:18,719
people came from that's what they're

1101
00:52:16,719 --> 00:52:20,209
looking for is the DNA that's in the

1102
00:52:18,719 --> 00:52:21,559
mitochondria you have the

1103
00:52:20,210 --> 00:52:24,199
plasma you have a whole bunch of

1104
00:52:21,559 --> 00:52:29,320
structures and this is where all the

1105
00:52:24,199 --> 00:52:31,879
biochemistry happens that that is life

1106
00:52:29,320 --> 00:52:34,400
whereas on this side these are the probe

1107
00:52:31,880 --> 00:52:36,410
the prokaryotes whether they're bacteria

1108
00:52:34,400 --> 00:52:38,389
or archaea they're really simple

1109
00:52:36,409 --> 00:52:39,980
they here's something that's called the

1110
00:52:38,389 --> 00:52:43,519
nucleoid

1111
00:52:39,980 --> 00:52:45,199
and all the DNA is is there and then you

1112

00:52:43,519 --> 00:52:47,239
can see there's just a couple of

1113
00:52:45,199 --> 00:52:55,608
structures in there so they're very

1114
00:52:47,239 --> 00:52:57,829
simple and of course on as we know from

1115
00:52:55,608 --> 00:53:00,230
you know everything that's the Eukarya

1116
00:52:57,829 --> 00:53:03,739
we have planned so they have solid cells

1117
00:53:00,230 --> 00:53:05,990
so the cells on this side ER are very

1118
00:53:03,739 --> 00:53:10,549
can be differentiated and have specific

1119
00:53:05,989 --> 00:53:13,519
purposes so here we go so life on Earth

1120
00:53:10,550 --> 00:53:14,269
the bacteria this is actually a picture

1121
00:53:13,519 --> 00:53:19,940
of e---coli

1122
00:53:14,269 --> 00:53:21,949
I had to find one that was a key this is

1123
00:53:19,940 --> 00:53:25,010
a meth an o-5

1124
00:53:21,949 --> 00:53:28,239
philic animal it loves methane and lives

1125
00:53:25,010 --> 00:53:30,740
where there's a lot of methane this is a

1126
00:53:28,239 --> 00:53:33,259

single-cell organisms rather than algae

1127

00:53:30,739 --> 00:53:34,819

and then here's the great white whale so

1128

00:53:33,260 --> 00:53:36,349

this side we have a lot of diversity

1129

00:53:34,820 --> 00:53:39,680

here we have a lot of diversity but

1130

00:53:36,349 --> 00:53:41,180

they're unicellular so then let's ask

1131

00:53:39,679 --> 00:53:47,449

the question of what would life on

1132

00:53:41,179 --> 00:53:51,169

Europa look like and it is probably not

1133

00:53:47,449 --> 00:53:54,348

going to be what we think of life it is

1134

00:53:51,170 --> 00:53:56,059

probably going to be something called

1135

00:53:54,349 --> 00:53:58,609

extremophiles now there are some

1136

00:53:56,059 --> 00:54:02,869

bacteria that are extremophiles and some

1137

00:53:58,608 --> 00:54:05,239

of these guys are extremophiles so these

1138

00:54:02,869 --> 00:54:09,108

are sort of the temperature ranges - 18

1139

00:54:05,239 --> 00:54:11,659

to 15 degrees Celsius 60 121 degrees

1140

00:54:09,108 --> 00:54:17,480

remember water at sea level boils at a

1141
00:54:11,659 --> 00:54:22,279
hundred degrees Celsius pressure is like

1142
00:54:17,480 --> 00:54:24,949
from 1/100 of an atmosphere to 1,300

1143
00:54:22,280 --> 00:54:26,599
times our nurse atmosphere so obviously

1144
00:54:24,949 --> 00:54:29,689
this would be at the bottom of the ocean

1145
00:54:26,599 --> 00:54:32,390
in the deep trenches this might be sort

1146
00:54:29,690 --> 00:54:33,860
of on the top of a mountain they can

1147
00:54:32,389 --> 00:54:38,420
live in places that are up to

1148
00:54:33,860 --> 00:54:42,550
38% salt and just as an example seawater

1149
00:54:38,420 --> 00:54:46,090
is only three percent salt whoops

1150
00:54:42,550 --> 00:54:51,620
some of them like to be really acid

1151
00:54:46,090 --> 00:54:54,289
sulfuric acid is about two and then we

1152
00:54:51,619 --> 00:54:57,349
have very basic eight to twelve most of

1153
00:54:54,289 --> 00:54:59,329
us love like seven and then some of them

1154
00:54:57,349 --> 00:55:00,110
can also withstand a lot of ionizing

1155
00:54:59,329 --> 00:55:02,420
radiation

1156
00:55:00,110 --> 00:55:05,360
so that would be x-rays gamma rays

1157
00:55:02,420 --> 00:55:07,639
ultraviolet even some of the products

1158
00:55:05,360 --> 00:55:10,039
from radioactive decay and they also

1159
00:55:07,639 --> 00:55:11,690
seem to be very resistant there are some

1160
00:55:10,039 --> 00:55:13,639
that are very resistant to cosmic rays

1161
00:55:11,690 --> 00:55:15,619
and you have to remember that for

1162
00:55:13,639 --> 00:55:19,279
example when people are talking about

1163
00:55:15,619 --> 00:55:22,489
traveling from Earth to Mars or to any

1164
00:55:19,280 --> 00:55:25,760
of the other planets humans one of the

1165
00:55:22,489 --> 00:55:29,059
things that people worry about in

1166
00:55:25,760 --> 00:55:30,620
transporting humans across space is the

1167
00:55:29,059 --> 00:55:34,070
effect of cosmic rays these are very

1168
00:55:30,619 --> 00:55:37,639
high-energy charged particles and they

1169

00:55:34,070 --> 00:55:39,530
damage cells and can lead to things like

1170
00:55:37,639 --> 00:55:42,409
like cancer and disease so that is

1171
00:55:39,530 --> 00:55:46,360
always a concern on say interplanetary

1172
00:55:42,409 --> 00:55:48,889
travel for humans is how to protect

1173
00:55:46,360 --> 00:55:50,030
living creatures from cosmic rays but it

1174
00:55:48,889 --> 00:55:53,779
turns out there are some of these

1175
00:55:50,030 --> 00:56:01,160
extremophiles that are happy to deal

1176
00:55:53,780 --> 00:56:03,560
with it so here I have two images here's

1177
00:56:01,159 --> 00:56:07,909
another bacterium this is actually a

1178
00:56:03,559 --> 00:56:13,369
hallow salt-loving bacterium and this is

1179
00:56:07,909 --> 00:56:15,699
a giant squid and Europa probably

1180
00:56:13,369 --> 00:56:19,849
doesn't have the giant squid so I think

1181
00:56:15,699 --> 00:56:23,269
we're going to see the bacteria and the

1182
00:56:19,849 --> 00:56:28,099
Archaea living in Europa and where would

1183
00:56:23,269 --> 00:56:32,239

they be found well here's a scale so

1184

00:56:28,099 --> 00:56:34,579

here's only some somebodies view the

1185

00:56:32,239 --> 00:56:38,119

view is that there is probably a

1186

00:56:34,579 --> 00:56:45,110

hypothermic vent or hyper thermal vents

1187

00:56:38,119 --> 00:56:46,690

in the deep ocean of Europa that heats

1188

00:56:45,110 --> 00:56:50,140

up the water

1189

00:56:46,690 --> 00:56:53,710

and then you sets up a convection which

1190

00:56:50,139 --> 00:56:56,769

allows the I want to call it the

1191

00:56:53,710 --> 00:56:59,769

nutritive 's but the basic elements that

1192

00:56:56,769 --> 00:57:05,880

are used by for biochemistry as we know

1193

00:56:59,769 --> 00:57:11,380

it carbon oxygen phosphorus etc and then

1194

00:57:05,880 --> 00:57:14,200

life bacteria archaea would end up

1195

00:57:11,380 --> 00:57:18,640

living at the bottom and sheets perhaps

1196

00:57:14,199 --> 00:57:21,969

or upside down mounds on the bottom of

1197

00:57:18,639 --> 00:57:25,059

the ice some of them might actually if

1198
00:57:21,969 --> 00:57:26,919
there were soft ice or a vent some of

1199
00:57:25,059 --> 00:57:29,380
these um living creatures might actually

1200
00:57:26,920 --> 00:57:32,019
end up working their way up to the

1201
00:57:29,380 --> 00:57:34,780
surface much the same way that rocks and

1202
00:57:32,019 --> 00:57:36,550
meteorites in the South Pole worked

1203
00:57:34,780 --> 00:57:38,859
their way up to the surface they just

1204
00:57:36,550 --> 00:57:40,568
get dredged up or I forget what the

1205
00:57:38,858 --> 00:57:44,230
actual word is for it

1206
00:57:40,568 --> 00:57:47,588
well dredged up by the physical forces

1207
00:57:44,230 --> 00:57:49,599
and from the surface of Europa you can

1208
00:57:47,588 --> 00:57:53,049
get some of the oxides

1209
00:57:49,599 --> 00:57:55,480
I think alum molecules with oxygen in

1210
00:57:53,050 --> 00:57:57,880
them might also make their way down sort

1211
00:57:55,480 --> 00:58:00,760
of in the same way through fissures in

1212
00:57:57,880 --> 00:58:03,099
the in the ice and so it is highly

1213
00:58:00,760 --> 00:58:07,990
likely that you would end up with life

1214
00:58:03,099 --> 00:58:13,000
on Europa living on the ice shelves and

1215
00:58:07,989 --> 00:58:16,779
so the next question is what comes next

1216
00:58:13,000 --> 00:58:18,818
and there are NASA has been looking at a

1217
00:58:16,780 --> 00:58:22,290
concept called the Europa clipper which

1218
00:58:18,818 --> 00:58:25,389
is a mission to go to Europa and

1219
00:58:22,289 --> 00:58:28,059
possibly fly through a plume and see if

1220
00:58:25,389 --> 00:58:30,068
any of these if there was any what's

1221
00:58:28,059 --> 00:58:32,019
what's in the plumes could there be some

1222
00:58:30,068 --> 00:58:34,719
biological material in the plumes

1223
00:58:32,019 --> 00:58:37,239
desiccated of course but would they be

1224
00:58:34,719 --> 00:58:39,669
there would it be possible to send some

1225
00:58:37,239 --> 00:58:41,979
type of a probe that would land on the

1226

00:58:39,670 --> 00:58:45,818
surface of Europa and perhaps be able to

1227
00:58:41,980 --> 00:58:48,460
either cozy up to one of those little

1228
00:58:45,818 --> 00:58:51,550
chaotic pieces of terrain or a soft spot

1229
00:58:48,460 --> 00:58:56,949
or near one of these plumes and actually

1230
00:58:51,550 --> 00:58:58,750
do some contact excavation and I I think

1231
00:58:56,949 --> 00:59:00,339
that would be really really cool so but

1232
00:58:58,750 --> 00:59:02,559
this is something that is being stai

1233
00:59:00,340 --> 00:59:08,470
very actively because this would be

1234
00:59:02,559 --> 00:59:10,719
perhaps Europa is after Earth's we were

1235
00:59:08,469 --> 00:59:15,549
we know there's life would is the next

1236
00:59:10,719 --> 00:59:18,639
most likely location suitable for liquid

1237
00:59:15,550 --> 00:59:21,400
carbon life as we know it in the solar

1238
00:59:18,639 --> 00:59:24,039
system and that would be super exciting

1239
00:59:21,400 --> 00:59:25,750
I think if something went there and we

1240
00:59:24,039 --> 00:59:28,449

discovered there was life there I think

1241
00:59:25,750 --> 00:59:30,909
it would also be super interesting if we

1242
00:59:28,449 --> 00:59:32,829
didn't find life there because then you

1243
00:59:30,909 --> 00:59:34,899
could ask the question was there ever

1244
00:59:32,829 --> 00:59:37,900
life how would you know would you be

1245
00:59:34,900 --> 00:59:40,690
able to find fossils on earth we do find

1246
00:59:37,900 --> 00:59:44,110
the people who look for them have found

1247
00:59:40,690 --> 00:59:47,740
fossilized bacteria so it's possible one

1248
00:59:44,110 --> 00:59:50,530
could find telltale signs of past life

1249
00:59:47,739 --> 00:59:55,659
or perhaps life hasn't actually started

1250
00:59:50,530 --> 00:59:58,380
yet these are all possibilities so I'm

1251
00:59:55,659 --> 01:00:03,219
just going to and here with one last

1252
00:59:58,380 --> 01:00:06,400
slide I don't know if it was Galileo's

1253
01:00:03,219 --> 01:00:08,799
dream to go to Europa or not in 400

1254
01:00:06,400 --> 01:00:12,329
years ago but I think he would certainly

1255
01:00:08,800 --> 01:00:17,500
be interested and would probably be a

1256
01:00:12,329 --> 01:00:20,699
promoter of exploring the icy moons this

1257
01:00:17,500 --> 01:00:27,090
also turns out to be a pretty good book

1258
01:00:20,699 --> 01:00:27,089
and so I will stop here

1259
01:00:27,780 --> 01:00:42,090
[Applause]

1260
01:00:39,949 --> 01:00:43,909
guess we have time for questions

1261
01:00:42,090 --> 01:00:45,990
oh we had plenty of time for questions

1262
01:00:43,909 --> 01:00:48,500
including a few that up here that

1263
01:00:45,989 --> 01:00:50,509
they're gonna come from online as well

1264
01:00:48,500 --> 01:01:02,670
[Laughter]

1265
01:00:50,510 --> 01:01:04,590
yes okay so I have to repeat the

1266
01:01:02,670 --> 01:01:06,329
question for the online audience can the

1267
01:01:04,590 --> 01:01:07,559
hub will be turned back on earth to look

1268
01:01:06,329 --> 01:01:11,909
for the same sort of things we might be

1269
01:01:07,559 --> 01:01:15,630
looking for on Europa the short answers

1270
01:01:11,909 --> 01:01:21,659
no Hubble is actually designed to avoid

1271
01:01:15,630 --> 01:01:24,680
looking down on Earth for logical

1272
01:01:21,659 --> 01:01:28,009
reasons but there are other satellites

1273
01:01:24,679 --> 01:01:30,899
whose missions are to look down on earth

1274
01:01:28,010 --> 01:01:33,480
so there are as a whole suite of Earth

1275
01:01:30,900 --> 01:01:36,920
observing satellites now I don't know

1276
01:01:33,480 --> 01:01:36,920
the details of whether they would have

1277
01:01:38,119 --> 01:01:48,359
all of the sensing equipment to be able

1278
01:01:44,130 --> 01:01:49,980
to look for life but I did that is not

1279
01:01:48,360 --> 01:01:51,900
that is one of the few things Hubble

1280
01:01:49,980 --> 01:02:13,289
cannot do is turn turn around and look

1281
01:01:51,900 --> 01:02:16,380
at and look at hers we're here that's

1282
01:02:13,289 --> 01:02:19,050
actually some okay so the question is

1283

01:02:16,380 --> 01:02:23,369
does that is does the effect of the

1284
01:02:19,050 --> 01:02:26,970
tidal forcing of the or the tidal

1285
01:02:23,369 --> 01:02:30,000
heating of Europa coincide with where

1286
01:02:26,969 --> 01:02:32,219
you see the plumes and in fact I just

1287
01:02:30,000 --> 01:02:36,510
read a paper on that and I think the

1288
01:02:32,219 --> 01:02:40,469
answer is no that is that is what in

1289
01:02:36,510 --> 01:02:41,880
fact Enceladus is locked but Europe is

1290
01:02:40,469 --> 01:02:43,289
not so I think that's one of the other

1291
01:02:41,880 --> 01:02:46,800
pieces of evidence that you we're not

1292
01:02:43,289 --> 01:02:49,900
looking at exactly the same thing in the

1293
01:02:46,800 --> 01:02:54,320
green sweater there yes

1294
01:02:49,900 --> 01:03:02,360
when the bottom I think you said it was

1295
01:02:54,320 --> 01:03:12,080
100 degrees Celsius when it comes I

1296
01:03:02,360 --> 01:03:13,370
would be like a 94 degrees Kelvin no cuz

1297
01:03:12,079 --> 01:03:15,619

you only see it on you only have a

1298

01:03:13,369 --> 01:03:17,829

little bit of 100 degrees Celsius as it

1299

01:03:15,619 --> 01:03:20,269

comes out and then it'll cool and

1300

01:03:17,829 --> 01:03:24,170

remember the ice is a hundred meters is

1301

01:03:20,269 --> 01:03:53,659

a hundred kilometers thick so the the

1302

01:03:24,170 --> 01:03:57,559

surface of Europa is so the question is

1303

01:03:53,659 --> 01:04:02,539

is the temperature on the surface of

1304

01:03:57,559 --> 01:04:05,929

Europa fluid and the answer is I'm not

1305

01:04:02,539 --> 01:04:07,759

sure because it well you know sometimes

1306

01:04:05,929 --> 01:04:11,059

Europa is facing the Sun so it's gonna

1307

01:04:07,760 --> 01:04:12,710

have a little more insulation I think

1308

01:04:11,059 --> 01:04:19,579

overall if we go back and look at those

1309

01:04:12,710 --> 01:04:23,240

beautiful images let's go back and look

1310

01:04:19,579 --> 01:04:25,940

at the numbers let's do the numbers so

1311

01:04:23,239 --> 01:04:29,319

what you see here is that you see it's

1312
01:04:25,940 --> 01:04:31,880
roughly about eighty to ninety degrees

1313
01:04:29,320 --> 01:04:35,240
Kelvin with a little bit maybe getting

1314
01:04:31,880 --> 01:04:37,910
up 230 so I don't know if that means

1315
01:04:35,239 --> 01:04:41,929
it's constantly changing but I think

1316
01:04:37,909 --> 01:04:43,069
it's pretty constrained obviously when

1317
01:04:41,929 --> 01:04:46,009
it's facing the Sun it's gonna be a

1318
01:04:43,070 --> 01:04:47,420
little hotter right yeah your image on

1319
01:04:46,010 --> 01:04:50,390
the right is it says the marked is

1320
01:04:47,420 --> 01:04:51,470
daytime and this is daytime and this is

1321
01:04:50,389 --> 01:04:53,869
nighttime here

1322
01:04:51,469 --> 01:04:56,539
so night so that there's probably a 30

1323
01:04:53,869 --> 01:04:58,639
degree change between the daytime and

1324
01:04:56,539 --> 01:05:02,690
the nighttime I don't I don't know that

1325
01:04:58,639 --> 01:05:03,078
means fluid okay so over here in the

1326
01:05:02,690 --> 01:05:05,088
black do

1327
01:05:03,079 --> 01:05:07,009
sure so generally then what is the

1328
01:05:05,088 --> 01:05:10,630
theory behind why's there's a certain

1329
01:05:07,009 --> 01:05:10,630
only a certain area where we're seeing

1330
01:05:13,690 --> 01:05:18,559
so the question is what is our

1331
01:05:16,369 --> 01:05:21,229
understanding of why we only see the

1332
01:05:18,559 --> 01:05:26,209
plumes in one location yeah good

1333
01:05:21,228 --> 01:05:29,149
question that's what we're trying to

1334
01:05:26,208 --> 01:05:30,858
understand actually and isn't that what

1335
01:05:29,150 --> 01:05:32,690
one of the things your rope a clipper

1336
01:05:30,858 --> 01:05:34,338
would be able to Europa clipper we'll be

1337
01:05:32,690 --> 01:05:37,700
able to probe a little better so there

1338
01:05:34,338 --> 01:05:39,889
like there was a question earlier and so

1339
01:05:37,699 --> 01:05:42,199
doing the comparison between Europa and

1340

01:05:39,889 --> 01:05:44,179
say some of the other moons not quite

1341
01:05:42,199 --> 01:05:47,419
seeing a direct analog particularly with

1342
01:05:44,179 --> 01:05:50,690
Enceladus so it is a it is an open

1343
01:05:47,420 --> 01:05:52,130
question and yes having a mission

1344
01:05:50,690 --> 01:05:54,099
actually go there and get really close

1345
01:05:52,130 --> 01:05:56,239
and personal would be a wonderful thing

1346
01:05:54,099 --> 01:05:57,469
right so there was a question on line

1347
01:05:56,239 --> 01:05:58,759
let me just interrupt with that that was

1348
01:05:57,469 --> 01:06:01,068
sort of related to the Europa clipper

1349
01:05:58,759 --> 01:06:03,739
they were wondering what all right so

1350
01:06:01,068 --> 01:06:05,719
they they recognized that like that yes

1351
01:06:03,739 --> 01:06:07,369
you have to go survey what would be the

1352
01:06:05,719 --> 01:06:09,289
time scale for a lander mission is what

1353
01:06:07,369 --> 01:06:12,108
they were asking I mean like when would

1354
01:06:09,289 --> 01:06:17,769

that happen yes if Europa clipper went

1355

01:06:12,108 --> 01:06:19,670

up next next decade would there be the

1356

01:06:17,768 --> 01:06:21,348

several people online were very

1357

01:06:19,670 --> 01:06:23,059

concerned that we need to be able to

1358

01:06:21,349 --> 01:06:29,239

measure the water on Europa before they

1359

01:06:23,059 --> 01:06:31,359

died yeah how old are they and where do

1360

01:06:29,239 --> 01:06:35,318

they live

1361

01:06:31,358 --> 01:06:39,159

I think it's likely within my my my

1362

01:06:35,318 --> 01:06:41,400

lifetime okay and I would hope in 20

1363

01:06:39,159 --> 01:06:41,399

years

1364

01:06:41,699 --> 01:06:46,210

all right so we'll just call it decades

1365

01:06:44,440 --> 01:06:48,369

okay yeah yeah it's not it's not gonna

1366

01:06:46,210 --> 01:07:04,230

happen next decade but I think in the

1367

01:06:48,369 --> 01:07:08,380

thirties would be a reason possible yeah

1368

01:07:04,230 --> 01:07:10,780

there are there are people on the on the

1369
01:07:08,380 --> 01:07:13,960
team that not me because I'm sort of a

1370
01:07:10,780 --> 01:07:16,150
you know lower level type player in this

1371
01:07:13,960 --> 01:07:20,039
but there are people there who have been

1372
01:07:16,150 --> 01:07:44,769
who are very active in talking to NASA

1373
01:07:20,039 --> 01:07:47,199
about that okay that's you the question

1374
01:07:44,769 --> 01:07:52,030
is House Cassini flew through the plumes

1375
01:07:47,199 --> 01:07:53,980
of Enceladus and made some measurements

1376
01:07:52,030 --> 01:07:56,140
of the of the chemistry and so the

1377
01:07:53,980 --> 01:07:57,548
question is if you went through the

1378
01:07:56,139 --> 01:08:04,088
plumes of Europa what would that

1379
01:07:57,548 --> 01:08:05,798
chemistry look like I'm not actually

1380
01:08:04,088 --> 01:08:08,739
sure I know the answer to that I think

1381
01:08:05,798 --> 01:08:12,000
it would depend on well you'd want to

1382
01:08:08,739 --> 01:08:14,919
see some evidence for example like

1383
01:08:12,000 --> 01:08:17,710
hydrogen compounds sulfate compounds

1384
01:08:14,920 --> 01:08:20,500
maybe iron compounds but I don't know

1385
01:08:17,710 --> 01:08:22,298
the quantity of hand would it matter

1386
01:08:20,500 --> 01:08:25,000
that much that Enceladus is sort of a

1387
01:08:22,298 --> 01:08:28,420
medium sized moon whereas Europa is a

1388
01:08:25,000 --> 01:08:31,539
large moon your open one of the seven

1389
01:08:28,420 --> 01:08:35,489
large moons Enceladus is just one of the

1390
01:08:31,539 --> 01:08:38,170
medium one of the many in size moons so

1391
01:08:35,488 --> 01:08:40,809
that's one of the major differences I

1392
01:08:38,170 --> 01:08:44,020
think of those two and then in addition

1393
01:08:40,810 --> 01:08:51,210
the cool thing would be to find

1394
01:08:44,020 --> 01:08:54,340
tyria all right in the back up there we

1395
01:08:51,210 --> 01:08:55,300
knew that there were was like when

1396
01:08:54,340 --> 01:08:58,380
Europe

1397

01:08:55,300 --> 01:09:01,050
what would the implication be for

1398
01:08:58,380 --> 01:09:13,060
because there's life in the solar system

1399
01:09:01,050 --> 01:09:17,730
big deal I think it certainly opens up

1400
01:09:13,060 --> 01:09:20,920
the definition of the habitable zone so

1401
01:09:17,729 --> 01:09:22,929
so the question is what is what is the

1402
01:09:20,920 --> 01:09:24,520
implication if life were found on Europe

1403
01:09:22,930 --> 01:09:27,220
or what is the implication for life in

1404
01:09:24,520 --> 01:09:28,960
the universe in in general so I'm gonna

1405
01:09:27,220 --> 01:09:32,530
back that up a little bit which is that

1406
01:09:28,960 --> 01:09:36,010
on earth wherever there is the

1407
01:09:32,529 --> 01:09:38,949
possibility of life there is life so

1408
01:09:36,010 --> 01:09:40,270
life is very tenacious and you know just

1409
01:09:38,949 --> 01:09:44,590
but just take that you know the basic

1410
01:09:40,270 --> 01:09:48,300
definition of life organic an organism

1411
01:09:44,590 --> 01:09:51,699

that can replicate and eats and poops

1412

01:09:48,300 --> 01:09:55,440

that's the basic definition of life and

1413

01:09:51,699 --> 01:09:55,439

moves it maybe moves around a little bit

1414

01:09:55,529 --> 01:09:59,729

if there's life on Europa that tells you

1415

01:09:58,390 --> 01:10:03,250

that you don't need to have direct

1416

01:09:59,729 --> 01:10:06,129

starlight whether its sunlight or or

1417

01:10:03,250 --> 01:10:07,449

that to provide the energy and that's a

1418

01:10:06,130 --> 01:10:09,579

little different because that's one of

1419

01:10:07,449 --> 01:10:11,679

the difficulties is on earth is knowing

1420

01:10:09,579 --> 01:10:12,970

exactly when you know you're no longer

1421

01:10:11,680 --> 01:10:15,520

dependent on sunlight so if you're in

1422

01:10:12,970 --> 01:10:17,740

the bottom of the ocean with the in the

1423

01:10:15,520 --> 01:10:19,660

trenches is the hydrothermal vents and

1424

01:10:17,739 --> 01:10:21,429

so forth you know you're not getting a

1425

01:10:19,659 --> 01:10:24,789

lot of sunlight down there at all

1426
01:10:21,430 --> 01:10:27,539
so that's a possibility so then when

1427
01:10:24,789 --> 01:10:29,949
people talk about looking for

1428
01:10:27,539 --> 01:10:31,239
extraterrestrial planets and looking for

1429
01:10:29,949 --> 01:10:32,500
evidence of life there's a whole

1430
01:10:31,239 --> 01:10:35,679
discussion of what's considered the

1431
01:10:32,500 --> 01:10:38,170
habitable zone hours some people call it

1432
01:10:35,680 --> 01:10:41,050
the Goldilocks you may have heard of it

1433
01:10:38,170 --> 01:10:43,420
as the Goldilocks a factor which is

1434
01:10:41,050 --> 01:10:45,369
where now you're looking at but there

1435
01:10:43,420 --> 01:10:48,940
you're looking at things like what could

1436
01:10:45,369 --> 01:10:51,099
be an earth as we know as we know Earth

1437
01:10:48,939 --> 01:10:54,639
if there's life on Europa what that

1438
01:10:51,100 --> 01:10:56,230
tells us I think is that the definition

1439
01:10:54,640 --> 01:10:57,910
of a habitable zone you can have one

1440
01:10:56,229 --> 01:11:00,009
four planets but you might also

1441
01:10:57,909 --> 01:11:02,260
to sort of think about all the

1442
01:11:00,010 --> 01:11:04,869
conditions that are necessary going back

1443
01:11:02,260 --> 01:11:08,110
to the basics of energy and chemistry

1444
01:11:04,869 --> 01:11:09,340
that are necessary so I think it opens

1445
01:11:08,109 --> 01:11:12,429
it up I think it also makes it much

1446
01:11:09,340 --> 01:11:13,930
harder to Wow if you're looking for

1447
01:11:12,430 --> 01:11:16,659
moons around Jupiter z-- and extra

1448
01:11:13,930 --> 01:11:19,000
terrestrial planets you'd make an

1449
01:11:16,659 --> 01:11:21,279
exoplanets it's a more difficult to find

1450
01:11:19,000 --> 01:11:23,619
but I think it would imply that it's

1451
01:11:21,279 --> 01:11:25,359
probably more prevalent this is now my

1452
01:11:23,619 --> 01:11:28,390
personal opinion it's more prevalent

1453
01:11:25,359 --> 01:11:30,369
than we might otherwise have expected

1454

01:11:28,390 --> 01:11:34,119
it's a long-winded answer to a short

1455
01:11:30,369 --> 01:11:38,949
question all right other questions

1456
01:11:34,119 --> 01:11:44,170
Peter another source of heat for Europa

1457
01:11:38,949 --> 01:11:45,989
like radioactivity so the question is

1458
01:11:44,170 --> 01:11:49,980
could there be another source of heat

1459
01:11:45,989 --> 01:11:54,399
like radioactivity from the core

1460
01:11:49,979 --> 01:11:56,739
probably but you know these let's say

1461
01:11:54,399 --> 01:12:00,009
these formed four-and-a-half billion

1462
01:11:56,739 --> 01:12:03,219
years ago four billion years ago I don't

1463
01:12:00,010 --> 01:12:04,750
think it would be enough I think you

1464
01:12:03,220 --> 01:12:18,550
would definitely need the title heating

1465
01:12:04,750 --> 01:12:20,560
to to keep that ocean liquid some of the

1466
01:12:18,550 --> 01:12:23,020
numbers I've seen like six to ten times

1467
01:12:20,560 --> 01:12:27,340
the amount of water on earth it's a huge

1468
01:12:23,020 --> 01:13:01,260

amount of water hey was there a question

1469

01:12:27,340 --> 01:13:04,779

in the back there other questions no I I

1470

01:13:01,260 --> 01:13:08,289

think it's possible it's probably less

1471

01:13:04,779 --> 01:13:10,389

likely yes tardigrades are very

1472

01:13:08,289 --> 01:13:15,609

tenacious and they are very tough

1473

01:13:10,390 --> 01:13:17,380

they're really hard to to do away with I

1474

01:13:15,609 --> 01:13:20,710

mean they're used in school in school

1475

01:13:17,380 --> 01:13:27,930

labs all the time because of that so

1476

01:13:20,710 --> 01:13:27,930

they they do have a chance a target

1477

01:13:39,689 --> 01:14:06,879

survive cosmic radiation but they are

1478

01:13:55,600 --> 01:14:08,380

multicellular yeah you if you don't know

1479

01:14:06,880 --> 01:14:11,699

about tardigrades you might want to look

1480

01:14:08,380 --> 01:14:14,440

them up my son at one of the science

1481

01:14:11,699 --> 01:14:16,029

centers we went to spend about half an

1482

01:14:14,439 --> 01:14:20,169

hour reading about the tardigrades and

1483
01:14:16,029 --> 01:14:23,380
it's really cool tardigrades are used

1484
01:14:20,170 --> 01:14:24,699
for in a lot of astrobiology labs when

1485
01:14:23,380 --> 01:14:25,840
they when they teach astrobiology

1486
01:14:24,699 --> 01:14:28,929
because it's one of those life forms

1487
01:14:25,840 --> 01:14:32,369
that is very tough and it you can

1488
01:14:28,930 --> 01:14:32,369
subject it to all sorts of conditions

1489
01:14:35,229 --> 01:14:48,238
[Laughter]

1490
01:14:40,019 --> 01:14:49,769
they're everywhere okay questions you've

1491
01:14:48,238 --> 01:15:11,549
had want to see if there's any other

1492
01:14:49,769 --> 01:15:14,099
okay back to you relationships so the so

1493
01:15:11,550 --> 01:15:17,940
the question is the fact that Jupiter is

1494
01:15:14,099 --> 01:15:20,400
a cat is a gaseous planet yeah because

1495
01:15:17,939 --> 01:15:22,888
that effect in the gravitational

1496
01:15:20,399 --> 01:15:35,129
relationship between the planet and its

1497
01:15:22,889 --> 01:15:38,670
moon because of the density yes yes it's

1498
01:15:35,130 --> 01:15:42,179
yes or no because if it's just gravity

1499
01:15:38,670 --> 01:15:45,989
then mass is more important than the

1500
01:15:42,179 --> 01:15:48,239
density so it's a total mass but the

1501
01:15:45,988 --> 01:15:49,948
fact that it has an atmosphere and has a

1502
01:15:48,238 --> 01:15:52,678
magnetic field so you start seeing

1503
01:15:49,948 --> 01:15:56,908
interactions of the magnetic field with

1504
01:15:52,679 --> 01:15:59,719
of Jupiter with its with its um plus the

1505
01:15:56,908 --> 01:16:02,788
the aurora which already you know it's a

1506
01:15:59,719 --> 01:16:04,590
it's a chemical reaction at a coming

1507
01:16:02,788 --> 01:16:08,639
it's a physical reaction so you you're

1508
01:16:04,590 --> 01:16:10,110
getting particles thrown into the

1509
01:16:08,639 --> 01:16:12,900
magnetic field so that will that will

1510
01:16:10,109 --> 01:16:14,670
affect so you could you can get

1511

01:16:12,899 --> 01:16:17,038
sputtering for example on the surface of

1512
01:16:14,670 --> 01:16:18,899
the of the moons that's when material

1513
01:16:17,038 --> 01:16:22,050
gets bombarded and then gets but gets

1514
01:16:18,899 --> 01:16:28,738
some sort of scraped off so the answer

1515
01:16:22,050 --> 01:16:31,940
is yes to both okay Herman okay

1516
01:16:28,738 --> 01:16:31,939
come in one last question

1517
01:16:34,689 --> 01:16:44,268
eating the course I don't think so no

1518
01:16:41,139 --> 01:16:47,809
all right so thank you all for coming on

1519
01:16:44,269 --> 01:16:50,449
next month may 1st gravitational wave

1520
01:16:47,809 --> 01:16:53,949
astronomy with Annie Fructis give

1521
01:16:50,448 --> 01:16:53,948
Suzanna one more big hand

1522
01:16:56,600 --> 01:17:06,039
[Applause]

1523
01:17:08,029 --> 01:17:11,130
[Music]